Multiphasic analysis of a recent record-breaking high temperature of 39.8 ºC in the Tokyo metropolitan area

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Introduction

Unclear points of the EHT events in the TMA

- Types of the EHT events
- Mechanism of the EHT events
  - (1) events with airflow over the mountain
  - (2) events with southeasterly wind
- Mechanism of foehn (one of the EHT factors)

⇩

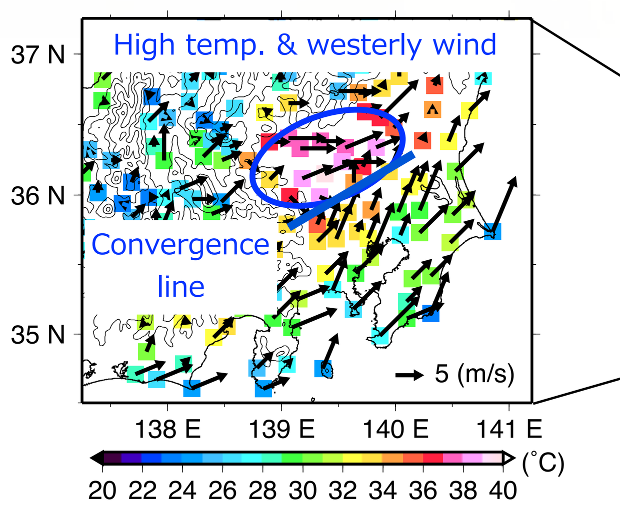
Purpose

The purpose of this study is to clarify quantitatively the formation mechanisms of the EHT event on June 24, 2011 (39.8 ºC observed at TMA), with a particular focus on the contributions from several types of foehn winds.

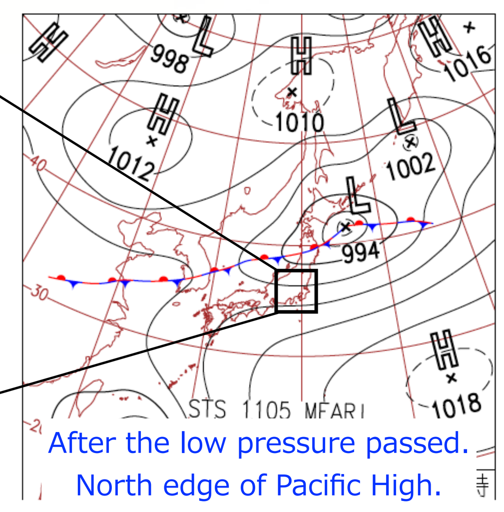
Observed features of the EHT event on June 24, 2011

June 24, 2011
EHT of 39.8 ºC observed at Kumagaya (record of June in Japan)

Surface air temp. & wind (14:20 JST)

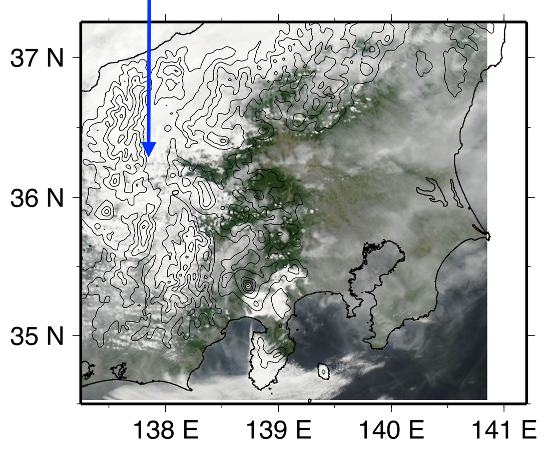


Surface weather chart at 09:00 JST

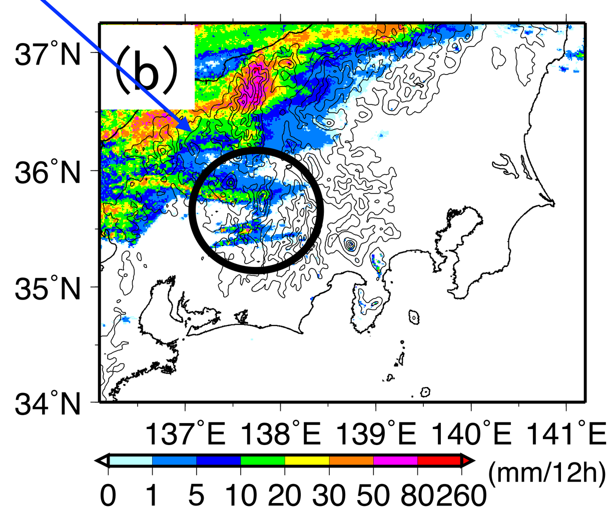


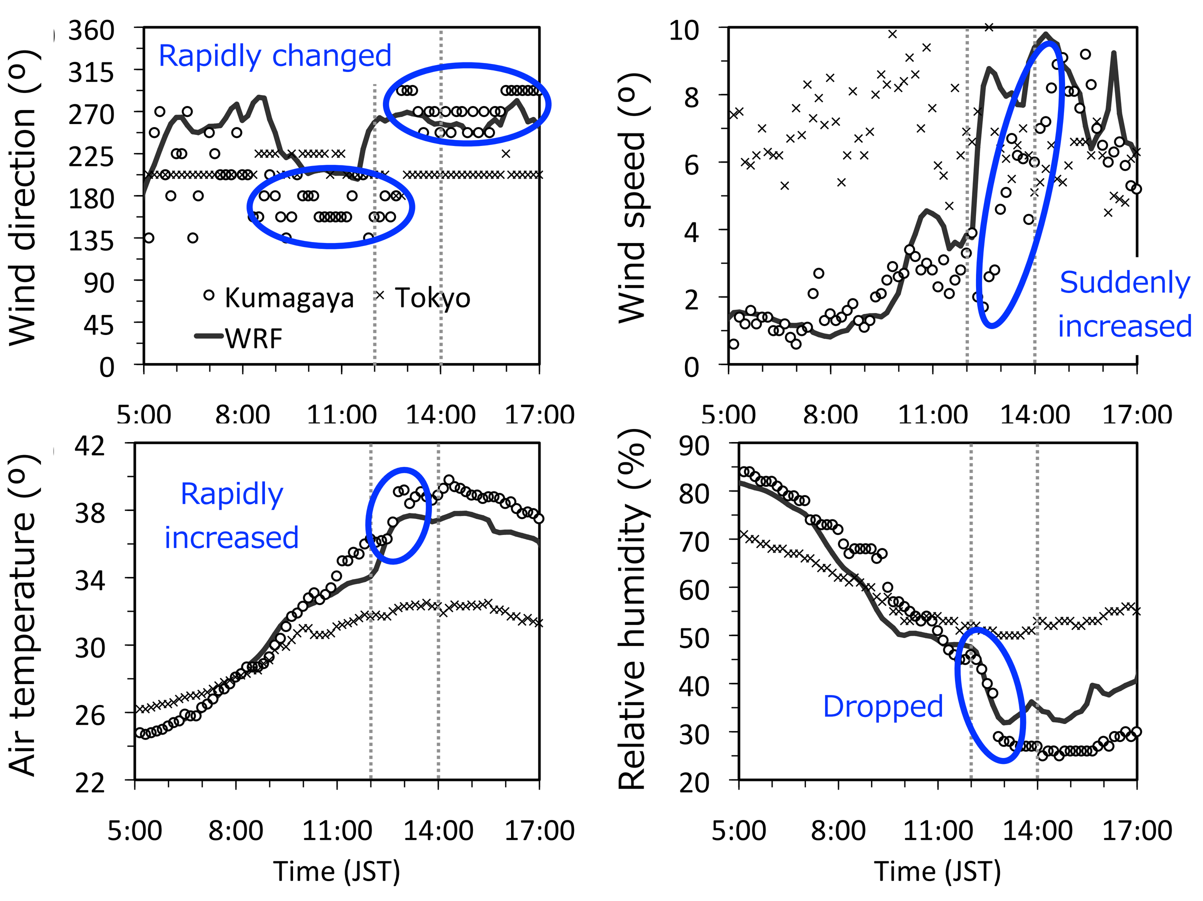
The upslope area of the Chubu Mountains was covered by clouds.
Precipitation observed this upslope area.

MODIS Terra (14:16 JST) Visible image



Amount of precipitation from 02:00 to 14:00 JST

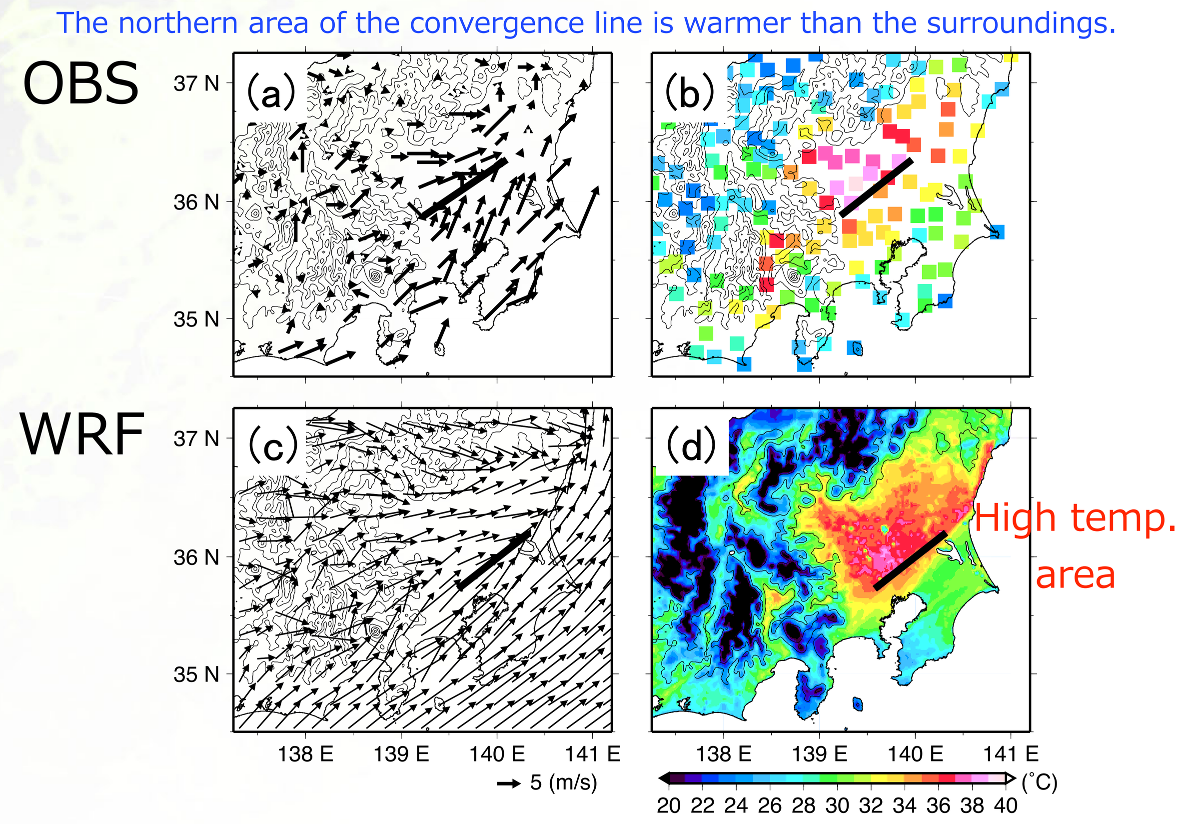


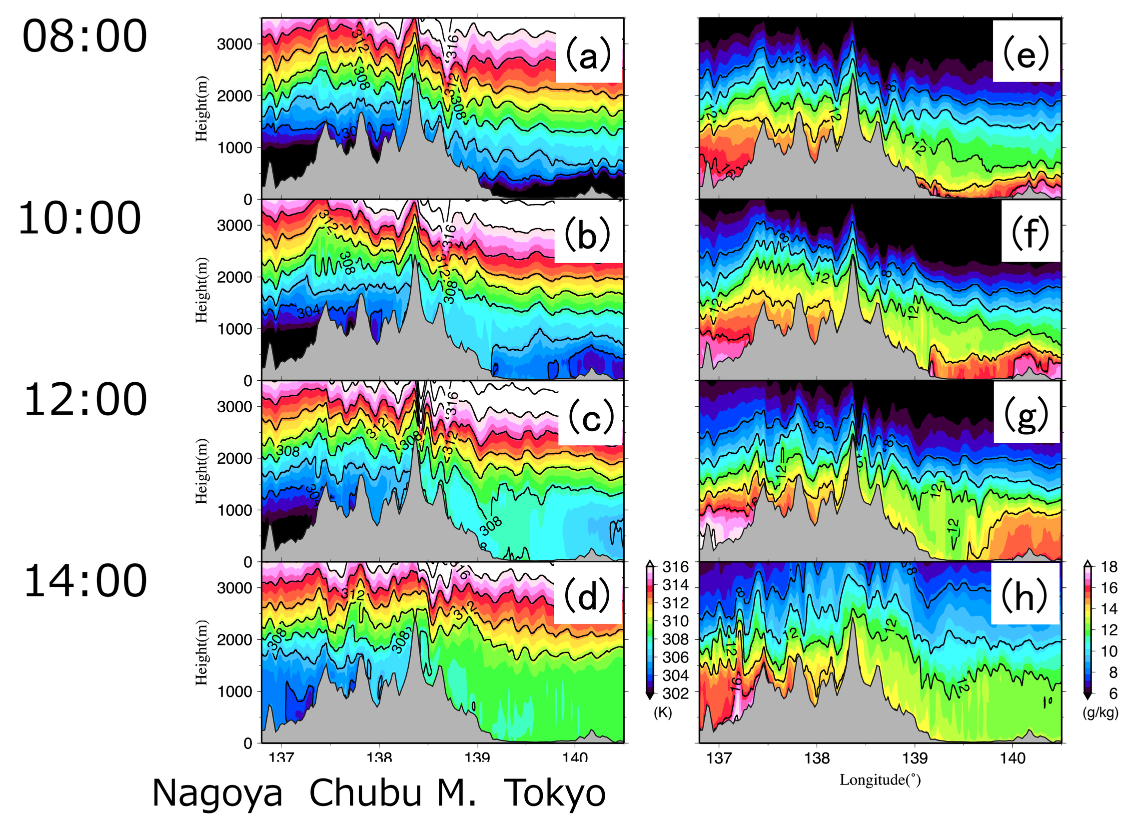


Numerical simulations (using the WRF ver.3.1.1)

※Horizontal resolution: 2 km, Initial & boundary conditions: JMA-MSM, NCEP-FNL, and RTG-SST
Boundary layer: Meller-Yamada-Janjic, Surface (no-urban): Noah-LSM, (urban): Single-Layer UCM

The WRF model successfully reproduces physical features of wind and temperature.
The northern area of the convergence line is warmer than the surroundings.





Euler heat budget analysis of a CV

The flux-form Euler equation of temperature

$$\partial_t \Theta + \left(\nabla \cdot \mathbf{V}\theta\right) = Q_\Theta$$

Grid-scale flux divergence; Forcing terms arising from model physics

① $NET = \int_{t_0}^{t_1} \frac{1}{M} \int_V \rho \partial_t \Theta \, dV dt$

The net heat input into the CV from t_0 to t_1 (K)

② $CONV = \int_{t_0}^{t_1} \frac{1}{M} \int_V \rho \nabla \cdot \mathbf{V}\theta \, dV dt$

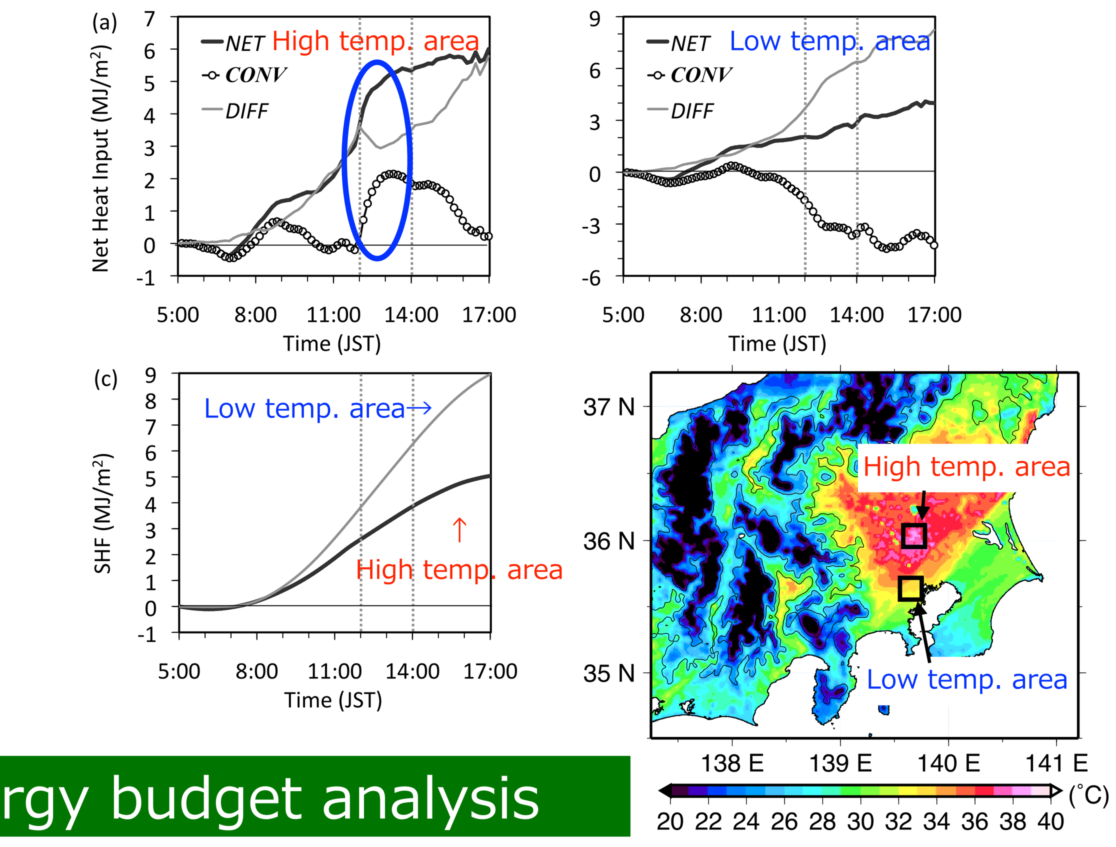
The net heat input due to grid-scale heat convergence from t_0 to t_1 (K)

③ $DIFF = NET - CONV$

The net heat input due to turbulent heat transport and diabatic heat input (the surface sensible heat and the radiation flux divergence) from t_0 to t_1 (K)

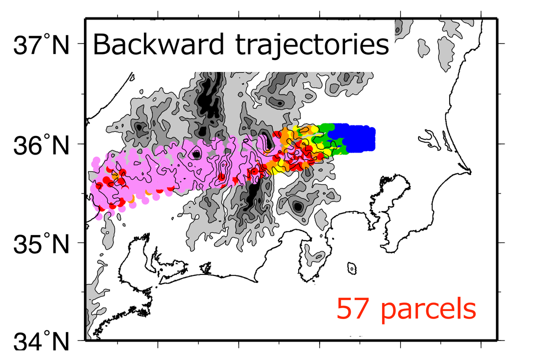
The *NET*, *CONV*, and *DIFF* are calculated with all horizontal and vertical grids on the analysis domain.

The time-integrated *NET* and *CONV* increase remarkable from 12:00 to 13:00 JST when the westerly wind penetrates into the high temp. area.



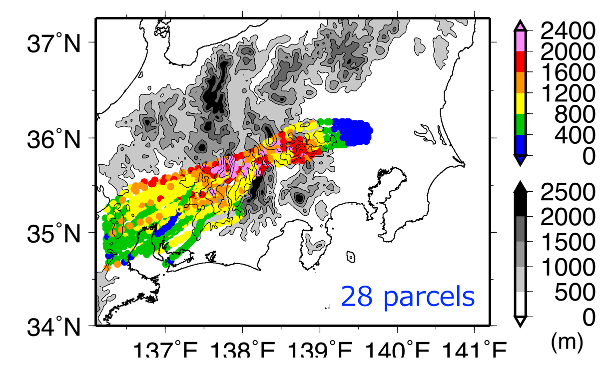
Backward trajectory and Lagrangian energy budget analysis

We track the trajectories of 100 air parcels released from the lowest level of the model grid in a 400 km^2 square area around the high temp area in the WRF model.
→The air parcels take mainly two causes: HIGH and LOW.



These air parcels are transported from the inland area of the Nohbi Plain over the 2,000 m height
57 parcels

Course HIGH

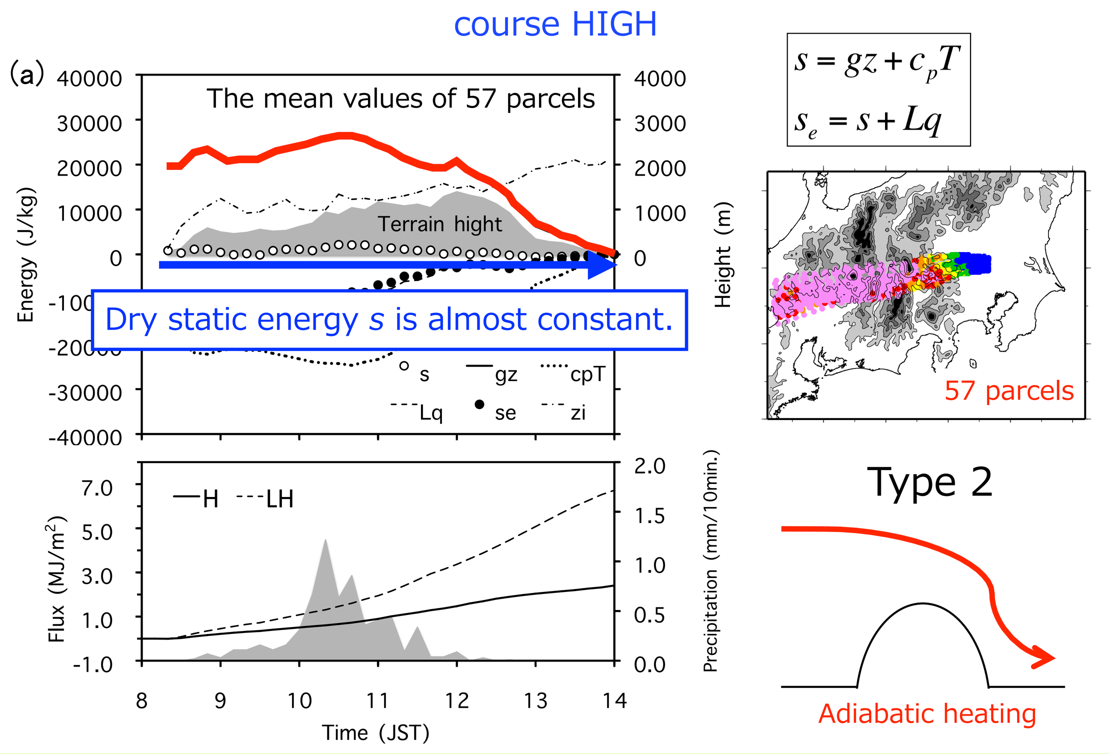


These air parcels are transported from the Nohbi Plain under the 800 m height
28 parcels

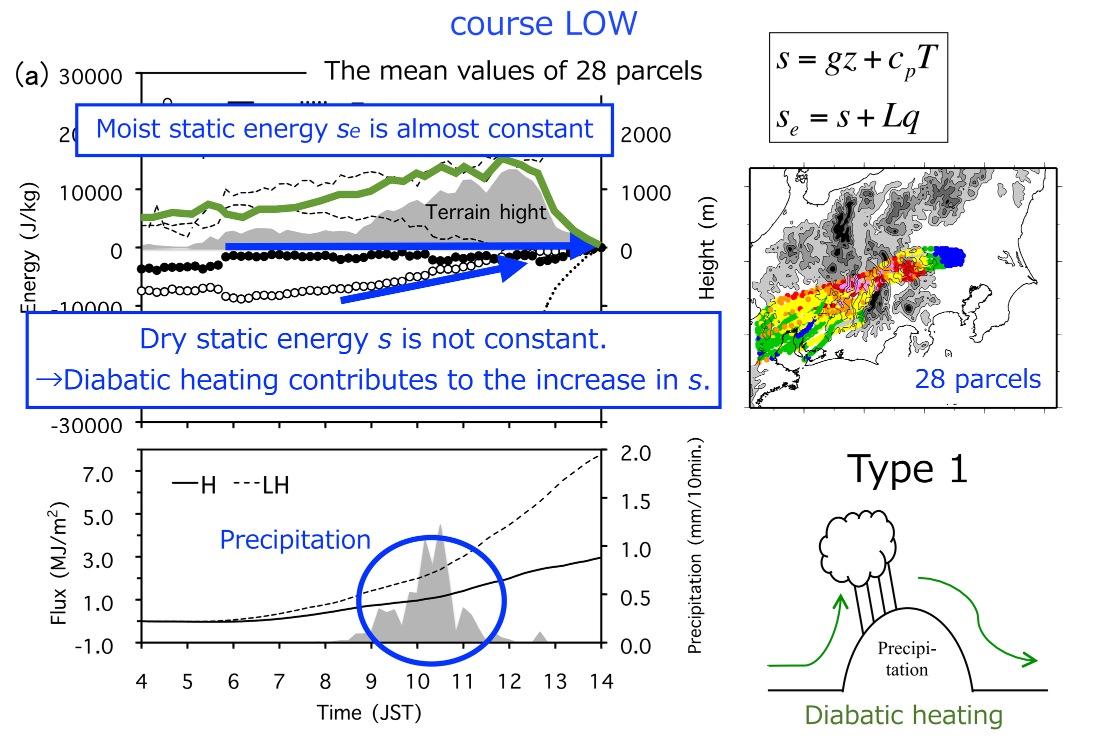
Course LOW

※Air parcels of the remaining 15 % take a hard-to-classify course.

The Lagrangian mean energy budget along the trajectories for course HIGH



The Lagrangian mean energy budget along the trajectories for course LOW



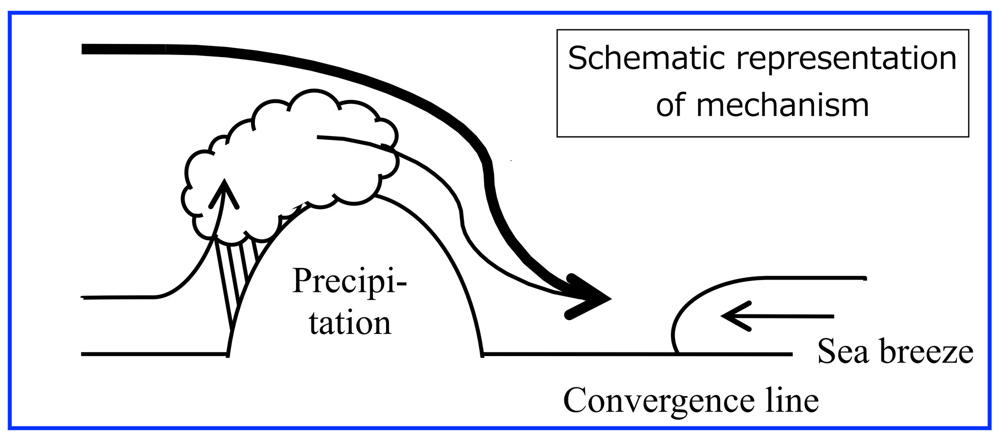
Conclusions

①The sunshine duration for the EHT day was 9.2 h, which was only the 411th longest sunshine duration for June-August and just the 125th longest in June for the period 1990–2011. Thus, the long sunshine duration was necessary, but it was not a sufficient condition to cause the EHT event.

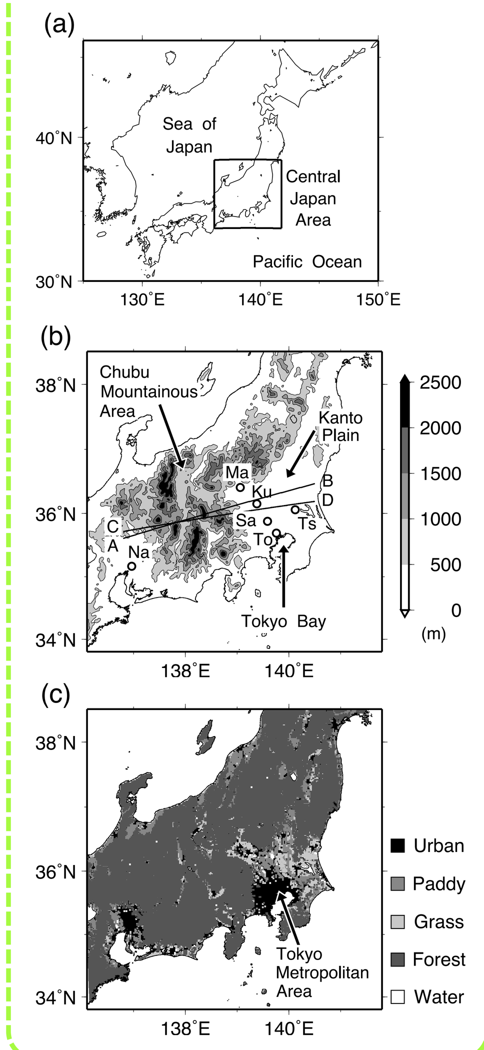
②The morning high temperature of 22.0 ºC near 1,500 m height was the 54th highest temperature in June to August, and 4th highest in June alone from 1990 to 2011. This high temperature was not a sufficient condition to cause the EHT event, although such a high temperature in the upper level would be a potential factor in the EHT event.

③The westerly wind on 24 June corresponded to a type "hybrid" foehn wind that arises when type 2 foehn flow cause by adiabatic heating combined with type 1 foehn wind caused by diabatic heating. This type notably contribute to the temperature increase after 12:00 JST in Kumagaya.

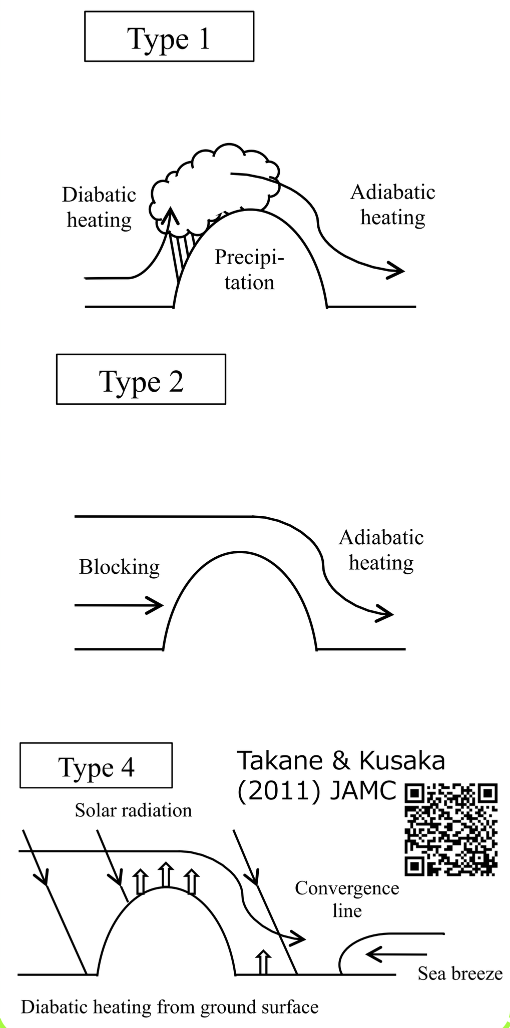
④Westerly winds blowing over the TMA prevented the sea breeze from penetrating with a cooler air mass, thus maintaining the high temperature region in the TMA.



Tokyo Metropolitan Area



Types of foehn



Takane & Kusaka (2011) JAMC

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RECCA S-8

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