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Synoptic Development of the Afternoon Thunderstorm Activity in An Over-Urbanized Valley: Taipei (Taiwan)

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Located in northern Taiwan, Taipei is a metropolis surrounded by hills and mountains that form a basin in which two river valleys funnel the surface airflow of this basin to the open sea. As a result of the southwest monsoon, the summer is dry for northern Taiwan but it happens to be the season of maximum rainfall in the Taipei basin. This unusual summer rainfall maximum in Taipei is produced mainly by afternoon/evening thunderstorms—particularly, on the downwind side and slopes of mountains south of the city. The population in the city of Taipei and the county in which this city is located has more than tripled during the past four decades, while land use for building and surface construction has increased by a factor of 3. This growing urbanization possibly may contribute to an increase of 1.5˚C in daily mean temperature, a 2/3 increase in the frequency of afternoon/evening thunderstorms, and a 3/4 increase in rainfall generated by thunderstorms.

The size of the Taipei valley is about 50km along the NE-SW direction and 30km along the NW-SE direction. The profound impact of urbanization on the afternoon thunderstorm activity in this valley stimulated our interest to explore the synoptic development involved with thunderstorms there. For this purpose, a field experiment was conducted for two summers (2004/05) in this valley; all identified thunderstorms were analyzed. Major findings are as follow:

1. Without the occurrence of an afternoon thunderstorm, surface pressure p_s and relative humidity RHs drop, and surface temperature Ts increases as soon as the sun rises, but the reversed situation occurs right after sunsets.
2. Thunderstorm rainfall begins when p_s reaches its afternoon minimum value. Reaching its minimum (maximum) value at the time when the rain falls, Ts (RHs) levels off. When the afternoon thunderstorm rainfall occurs, the sea breeze switches directions immediately and becomes the land breeze. The land breeze from the mountain slope and foothills in the southern side of this valley propagate the rainfall along the two rivers to the sea within an hour.

It was also revealed from our analysis that several parameters (p_s, Ts, and RHs) can be used as precursors of the afternoon thunderstorm inside this valley:

1. Maximum p_s(thunderstorm day) in early morning is significantly smaller than p_s(non-thunderstorm day).
2. RHs(thunderstorm day) ($\geq 80\%$) is about 10$\sim$15% more than RHs(non-thunderstorm day) before noon.
3. Maximum Ts(thunderstorm day) value occurs at about 11:30am, an hour earlier than the maximum Ts(non-thunderstorm day).
4. At 00UTC, i.e. 08LST, the lowest 10-m layer above the surface is unstable on the thunderstorm day: Ts(thunderstorm day) $>$ T_{10m}(upper-air sounding), but it is more or less stable on the non-thunderstorm days.

During the thunderstorm day, Taiwan is juxtaposed between a cyclonic anomalous circulation NW of Taiwan and an anticyclonic anomalous circulation SE of Taiwan. This juxtaposition of anomalous circulations enhances the moisture transport to Taiwan. The opposite condition occurs on the non-thunderstorm day.