Characterization of the Boundary Layer Structures and Local Airflow over the Complex Terrain in Taiwan using High resolution WRF model

Yu-Tzu Wang[1], Fang-Yi Cheng[1] and Hyeyum Hailey Shin[2]

[1]Department of Atmospheric Sciences, National Central University, Taiwan

[2] National Center for Atmospheric Research (NCAR), Boulder, Colorado

Email

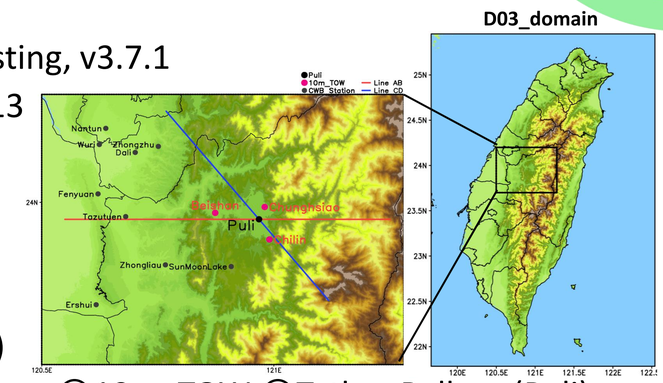
Introduction

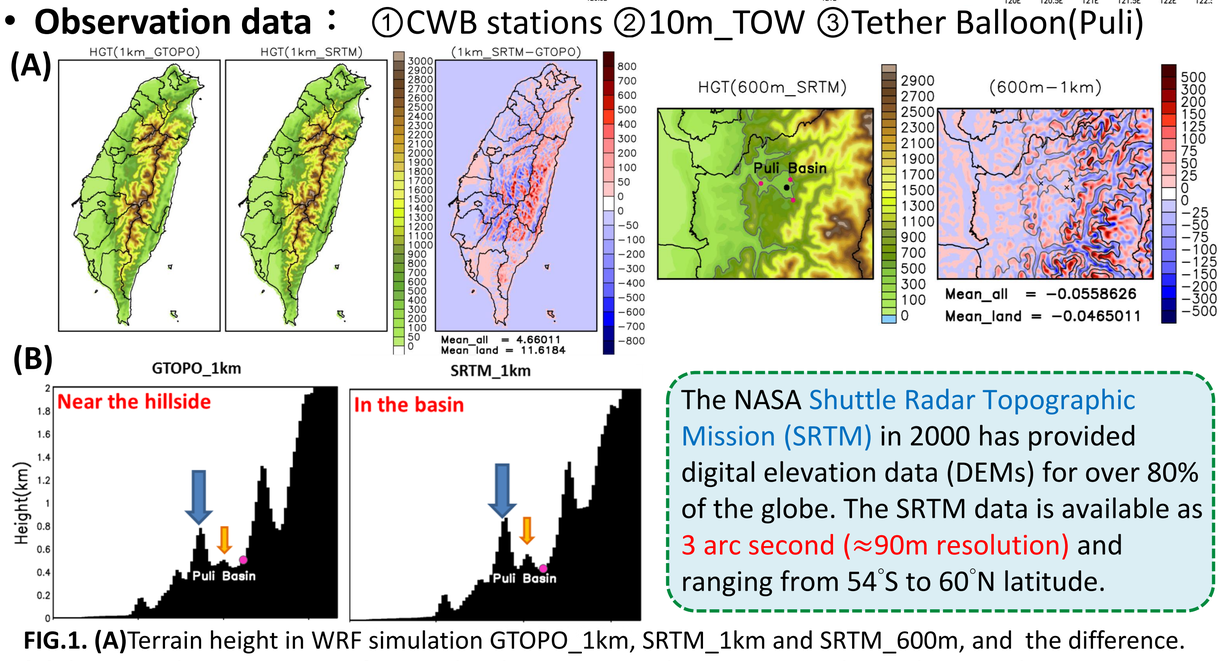
Puli basin is located in the central mountainous area of Taiwan, the surrounding terrain height is about 800 to 2000m. Over the mountainous area, it is difficult to accurately simulate the development of atmospheric motions. In order to understand the characteristics of local circulation and the planetary boundary layer (PBL) structures over the complex terrain in Taiwan, the Weather Research and Forecasting (WRF) Model at fine resolution (600-m) was applied with the high resolution terrain data. In addition, two different PBL scheme (Yonsei University, YSU and Shin-Hong scale-aware, SH) were applied to study the influence of the PBL physical processes on the simulated vertical structures.

Simulation results were evaluated with the surface station and observed sounding data to characterize the PBL structures and local air flow over the central mountainous area of Taiwan.

Numerical Model and Data

- **Model**：
  The **W**eather **R**esearch and **F**orecasting, v3.7.1
- **Simulation time**：Sep. 02-08, 2013
- **Horizontal resolution**：
  D01-15km, D02-3km,
  D03-1km & 600m
- **Initial and boundary condition**：
  EC_ERA5 Reanalysis data (0.3°x0.3°)
- **Observation data**： ①CWB stations ②10m_TOW ③Tether Balloon(Puli)

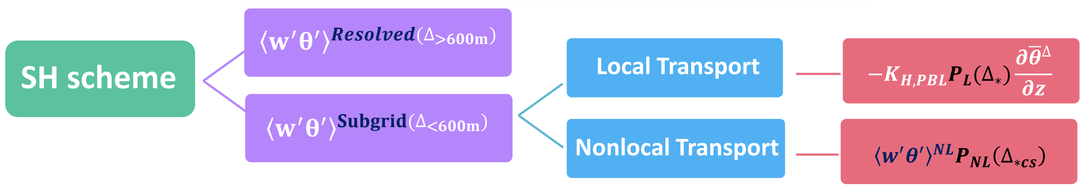




The NASA Shuttle Radar Topographic Mission (SRTM) in 2000 has provided digital elevation data (DEMs) for over 80% of the globe. The SRTM data is available as 3 arc second (≈90m resolution) and ranging from 54°S to 60°N latitude.

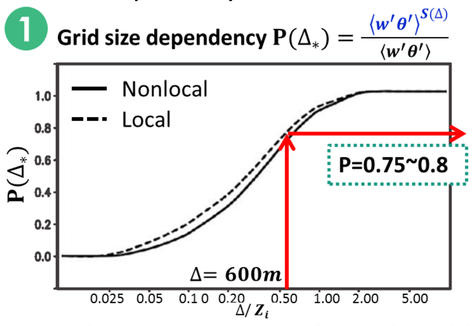
FIG.1. (A) Terrain height in WRF simulation GTOPO_1km, SRTM_1km and SRTM_600m, and the difference. **(B)**The vertical cross sections of terrain height in WRF simulation GTOPO_1km and SRTM_1km.

Shin-Hong scale aware scheme

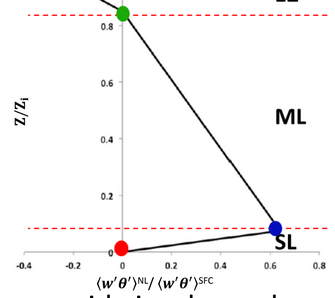


- The nonlocal transport by strong updrafts and local transport by remaining small-scale eddies are separately calculated.

1 Grid size dependency $P(\Delta_*) = \frac{\langle w'\theta' \rangle^{S(\Delta)}}{\langle w'\theta' \rangle}$



2 Vertical profiles of $\langle w'\theta' \rangle^{NL}$



1. The SGS heat transport is formulated by multiplying a grid-size dependency function with the total transport profile fitted to the Large-eddy simulation (LES) output.
2. SGS nonlocal transport: ①Surface Layer cooling ②Mixed Layer heating③Entrainment

Result

➤An overview of simulation result

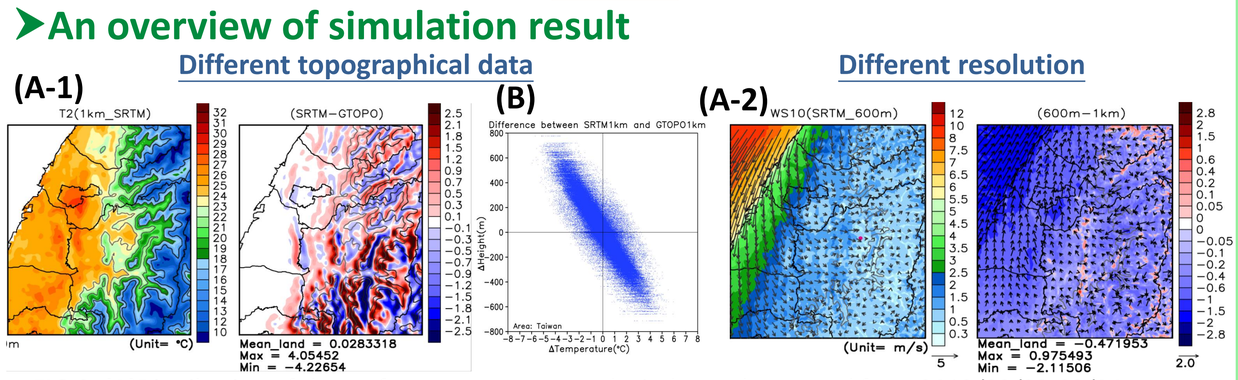


FIG.2. (A) Distribution of the surface temperature and wind speed averaged from 2013/09/03-09/04. **(B)**Scatter plot of difference (SRTM-1km minus GTOPO-1km) between temperature and terrain height.

➤ Comparison between Simulation and Observation

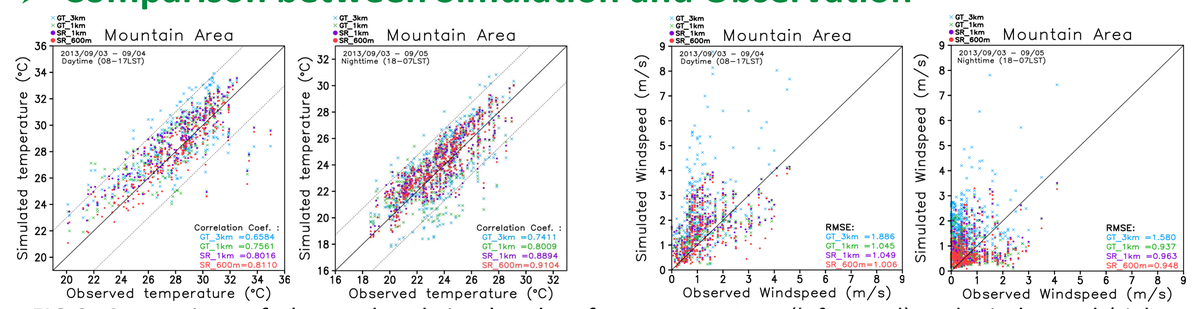


FIG.3. Comparison of observed and simulated surface temperature (left panel) and wind speed (right panel) at different grid resolution during nighttime and daytime over the mountainous area. (Solid line denotes the one to one line; dash line denotes the range of one standard deviation)

➤ The Structures of PBL and Local Airflow

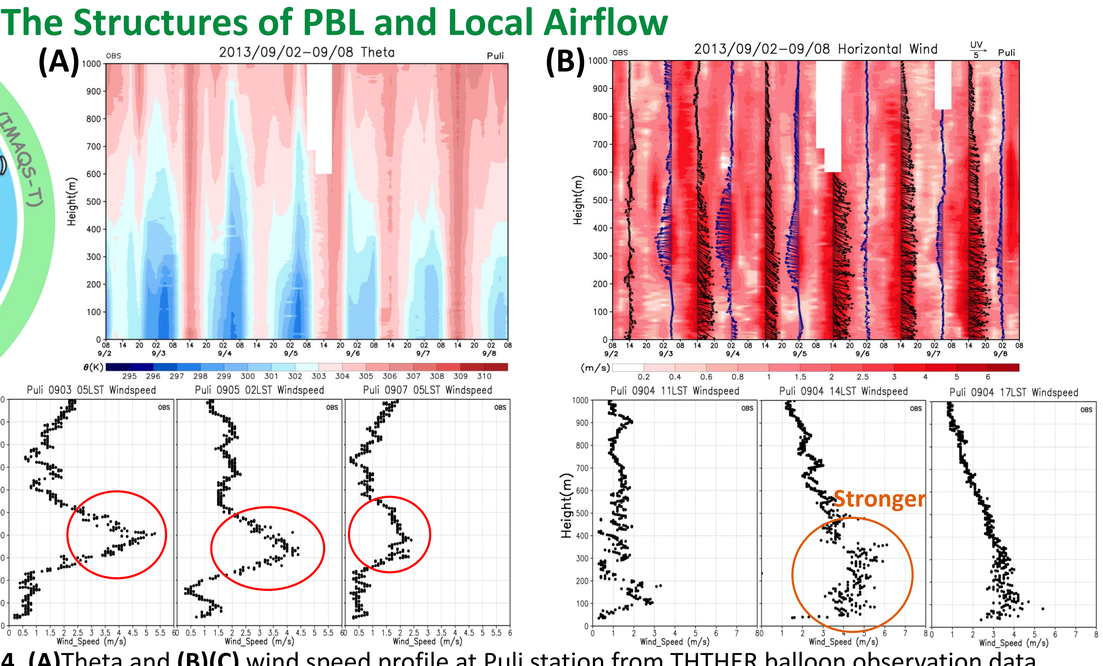


FIG.4. (A) Theta and **(B)(C)** wind speed profile at Puli station from THTHER balloon observation data.

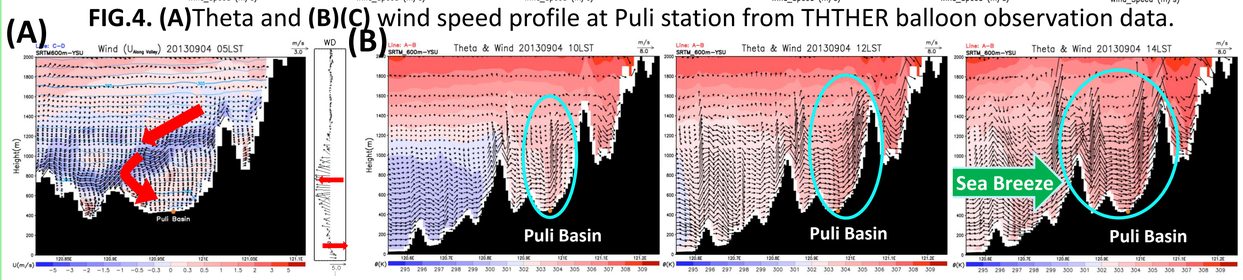


FIG.5. (A) Vertical cross-section of wind speed (shaded) and wind vector (u;w*10) during the nighttime. **(B)**As same as (A) but for theta(shaded) during the daytime.

- ➤ During the daytime, atmosphere become well-mixed and the westerly flow which is composed of sea breeze and up-valley wind prevails in the basin.
- ➤ During the nighttime, there is strong easterly wind produced by downslope wind in the upper level. It also interacts with the topography and causes the westerly wind in the near surface layer.

➤ Comparison with different PBL scheme

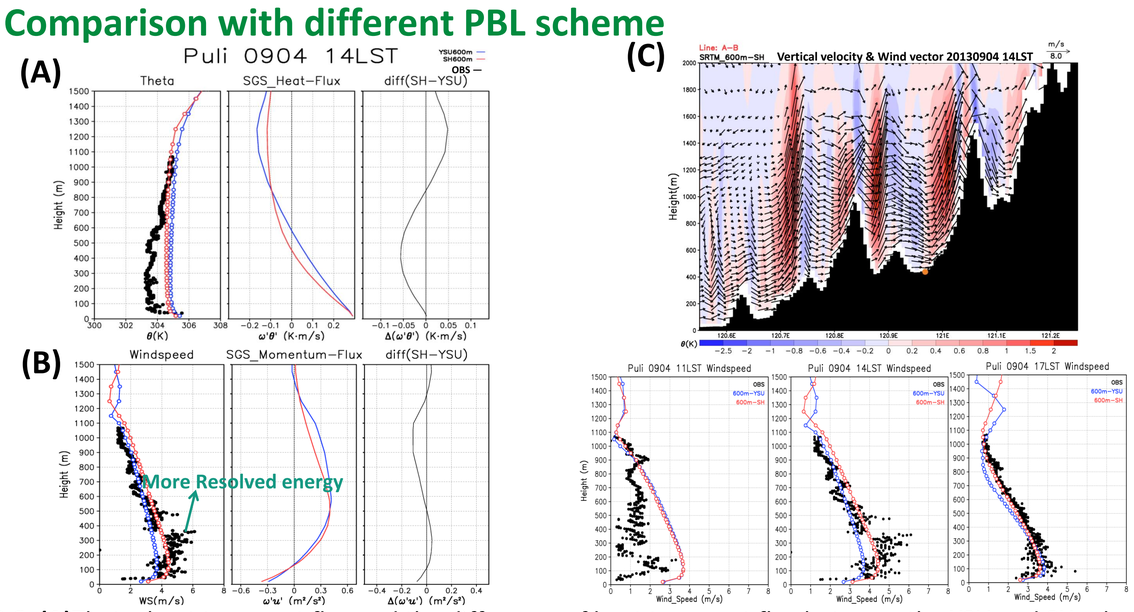


FIG.6. (A) Theta, heat transport flux and the difference of heat transport flux between the YSU and SH scheme. **(B)**As same as (A), but for wind speed and momentum transport flux. **(C)**Vertical cross-section of vertical velocity W (shaded) and wind vector (u;w*10) in SH scheme.

- ➤ Although the both of the model simulations produced a warm bias in theta profile, the smaller bias was from the SH scheme which caused by the weaker entrainment flux from the upper level and weaker upward heat flux from the surface.
- ➤ Due to the more vertical transport flux could be resolved by the model, the more turbulent energy would be calculated. It causes a stronger westerly wind in the near surface layer and highlights the characteristics of observation.

Summary

- The use of the high resolution topographical data from SRTM of the fine scale WRF simulation at 600-m resolution enhances the model performance and it also helps characterize the PBL structures and local air flow in puli basin.
- By using Sing-Hong PBL scheme with the scale dependency, the resolved motion can be improved and the simulated convection structure can be maintained at the gray zone resolution.
- The results from Shin-Hong PBL scheme show the better simulation of the theta and wind speed profile compare to the YSU scheme, and highlight the characteristics of observation such as a strong westerly wind in the near surface in the afternoon.

Reference

- Shin, H. H., and S.-Y. Hong, 2015: Representation of the Subgrid-Scale Turbulent Transport in Convective Boundary Layers at Gray-Zone Resolution. *Mon. Wea. Rev.*