The characteristics of cold pools over complex topography in TaiwanVVM

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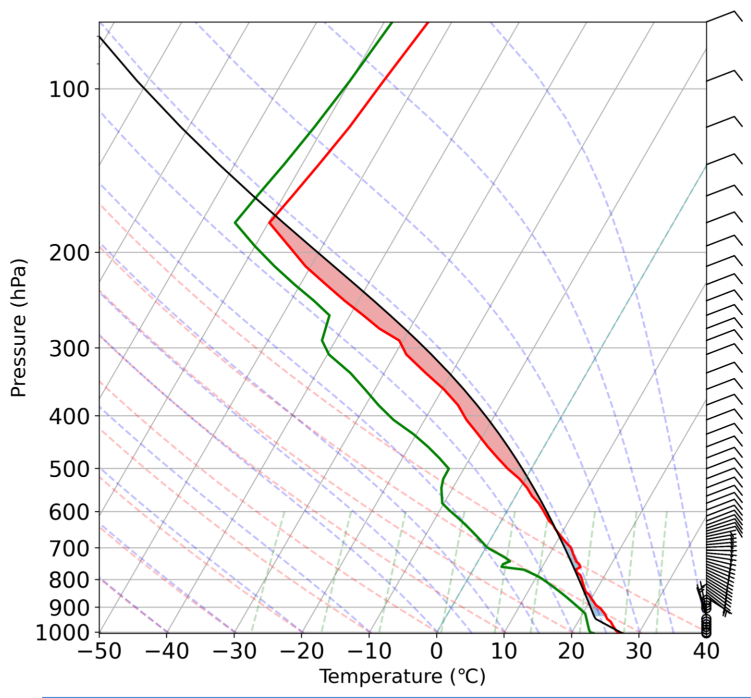
Objective and Motivation

- In this study, we modify the algorithm of finding cold pools over complex topography from negative buoyancy method.(Tomkins,2001a and Feng et al., 2015). This method calculates the virtual potential temperature spatial anomaly and take the integral in vertical direction then get the cold pool intensity.
- In previous studies, the cold pools calculation mainly focus on the plane or ocean region. Under homogeneous surface property, the benchmark of spatial anomaly uses a fixed synoptic domain averaged.
- With smaller convection and topography scale (about 1 to 10km) like in Taiwan, we use the size of precipitation object to calculate the benchmark. From the result, the cold pool spatial structure is more reasonable under weak synoptic scale simulation.

Model and Experiments Design

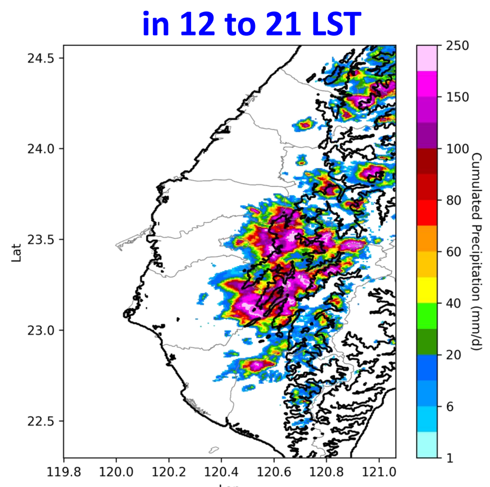
Model name (Atmosphere)	Taiwan Vector Vorticity Model (TaiwanVVM)
Model name (Land)	Noah Land Surface Model (LSM)
Horizontal size Resolution	1024 x 1024km 500 x 500 m
Vertical grid	70 levels under 4000 m is constant height with the difference 100m, above 4000m is stretching grid
Simulation Time	24 hrs
Time step	10 sec
Initial condition	One of the typical weak synoptic scale in summer from Chang et al., 2021
Boundary condition	Double periodic with fixed SST With coupled Taiwan 500m resolution topography and land use data

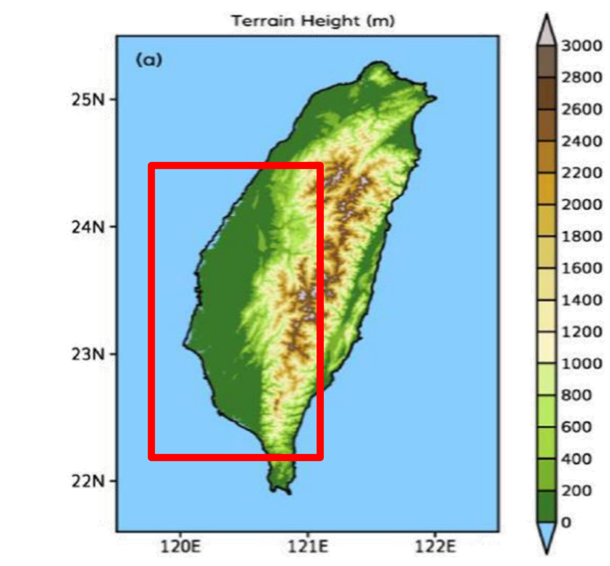
Initial Profile



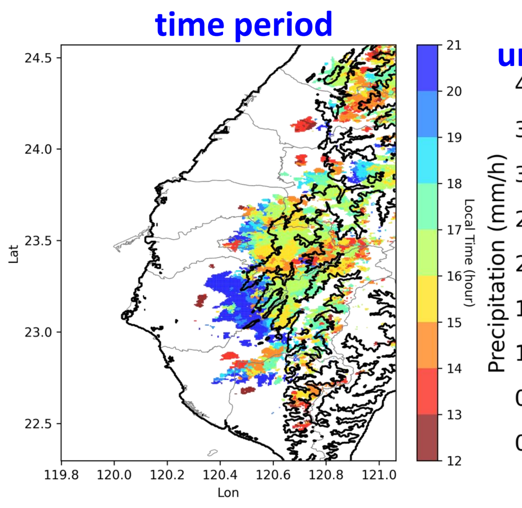
Result of simulation

The cumulated precipitation in 12 to 21 LST

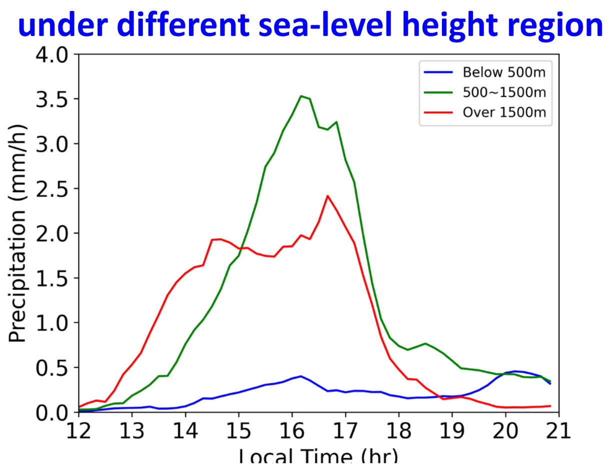




The maximum precipitation time period

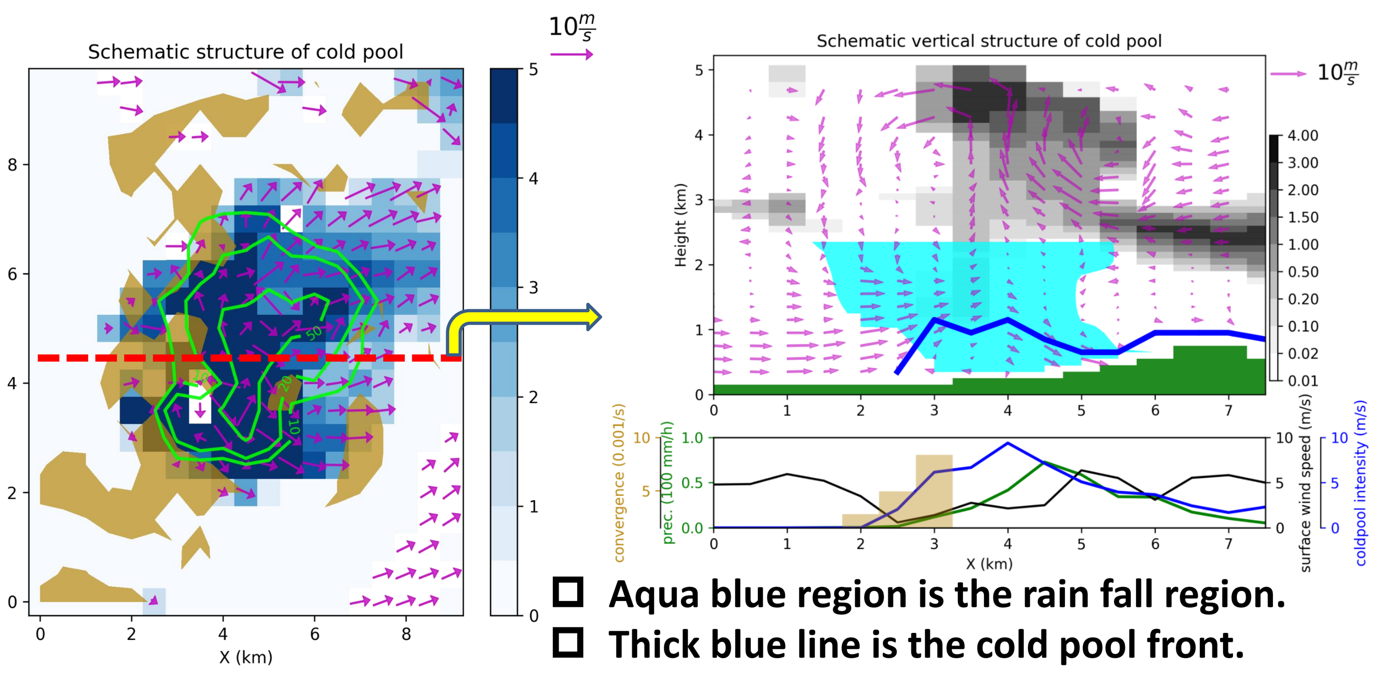


Precipitation evolution under different sea-level height region



- In this weak synoptic simulation in summer, the precipitation hotspot is near the foot of the mountain (up to 200 $mm\ d^{-1}$), and it mainly occurred in the afternoon(about 14 to 17 LST).
- From the time evolution, it shows the precipitation in the mountain(over 1500m) occurred earlier than in the halfway up the mountain (500~1500m), which is the convection development from mountain top heating.
- The precipitation in the halfway up the mountain might from the convergence from the sea breeze and the convection outflow in the mountain.

Schematic plot of cold pool structure



- Aqua blue region is the rain fall region.
- Thick blue line is the cold pool front.
- In front of the cold pool front, it gets strong convergence intensity.
- Blue shaded is the cold pool intensity(ms^{-1}). Purple vector is the surface wind(ms^{-1}).
- Green contour is the precipitation. Gold region is the surface convergence zone where the value over $1.5\times10^{3}(s^{-1})$.

Method

Virtual Potential Temperature (K)

$$\theta_p = \theta(1 + 0.608q_{vapor} - q_{cloud} - q_{rain})$$

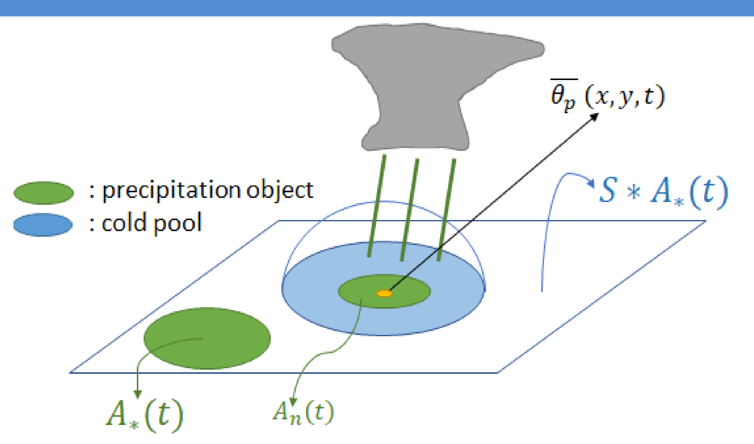
Buoyancy $(ms^{-2}) < -0.003$

$$b = \frac{g(\theta_p - \overline{\theta_p})}{\overline{\theta_p}}$$

Cold pool intensity (ms^{-1})

$$B = \sqrt{-2\int_0^h b\, dz}$$

[Feng et al., 2015]

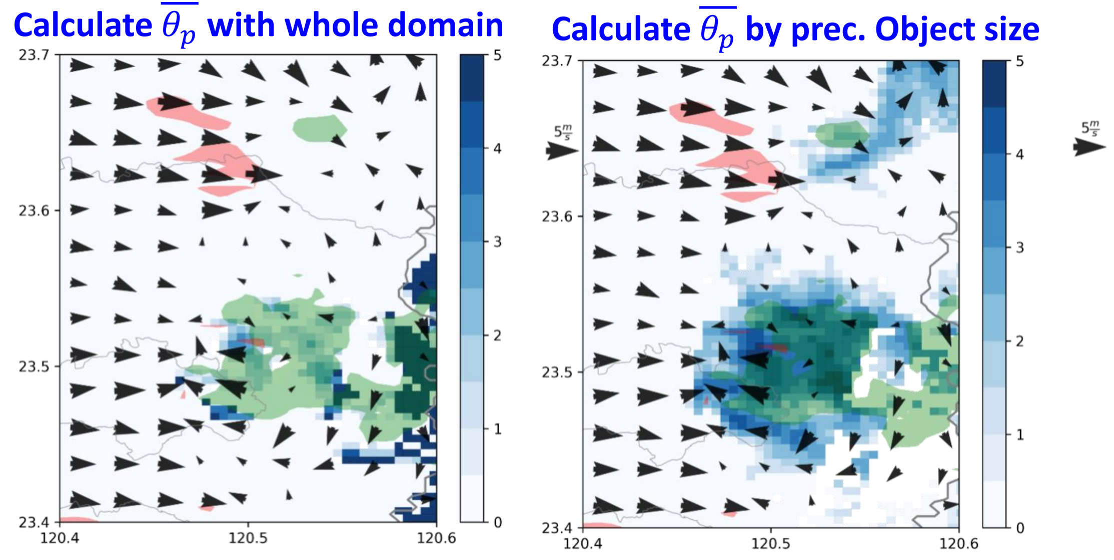


- A_n(t) is one precipitation object size per time period.
- $S * A_*$(t) is the feature size for the time period.

This value is for the spatial size calculating $\overline{\theta_p}$.

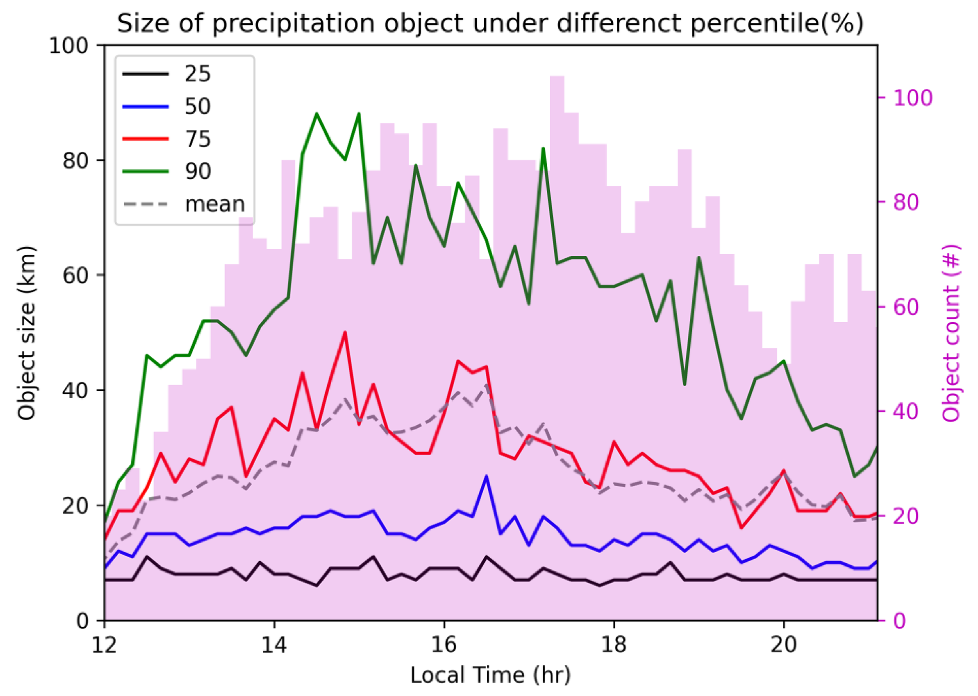
Results

Calculate $\overline{\theta_p}$ with whole domain / Calculate $\overline{\theta_p}$ by prec. Object size



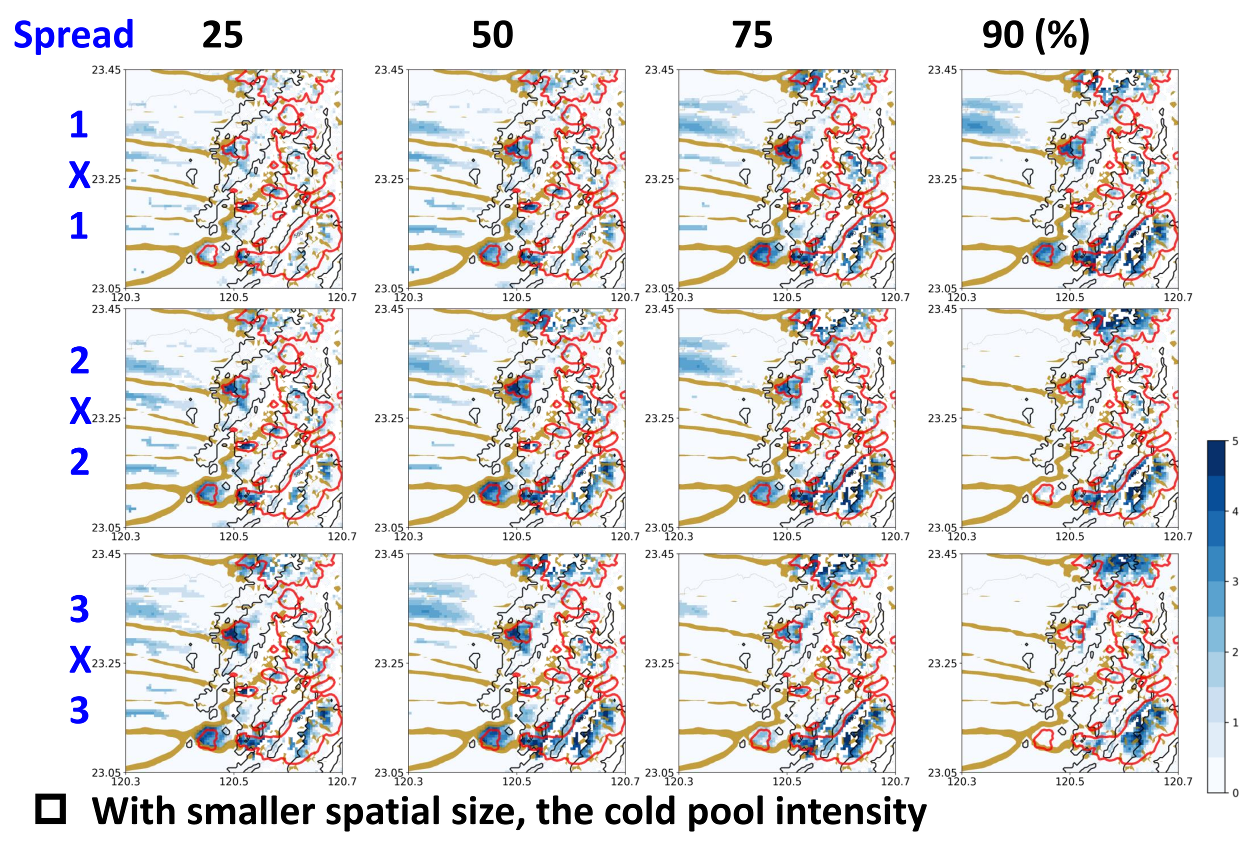
- Blue shaded is the cold pool intensity. Green region is the precipitation.

Vector is the surface wind.
- Left figure is using the whole grid point on land in the red box region in South Taiwan to calculate the $\overline{\theta_p}$, which the cold pool region mismatches with the precipitation region.
- From the right figure, it gets more reasonable cold pool region with the precipitation region.

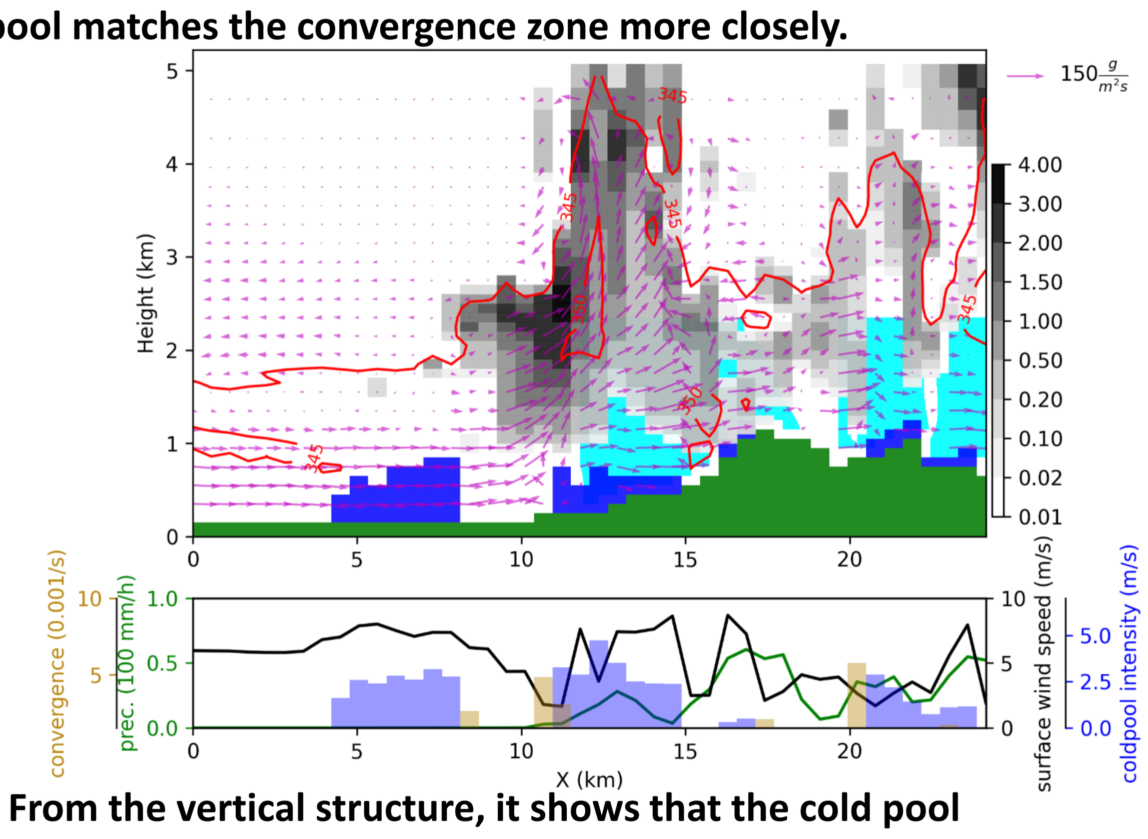


- This figure shows the evolution of the precipitation object size distribution under different percentile, which provides the information of rainfall system size feature in South Taiwan in every time period.
- Next we use the different percentile(25,50,75,90%) and spread ratio to test the sensitivity of the cold pool region, and compare with the surface convergence zone to quantify the reasonability.

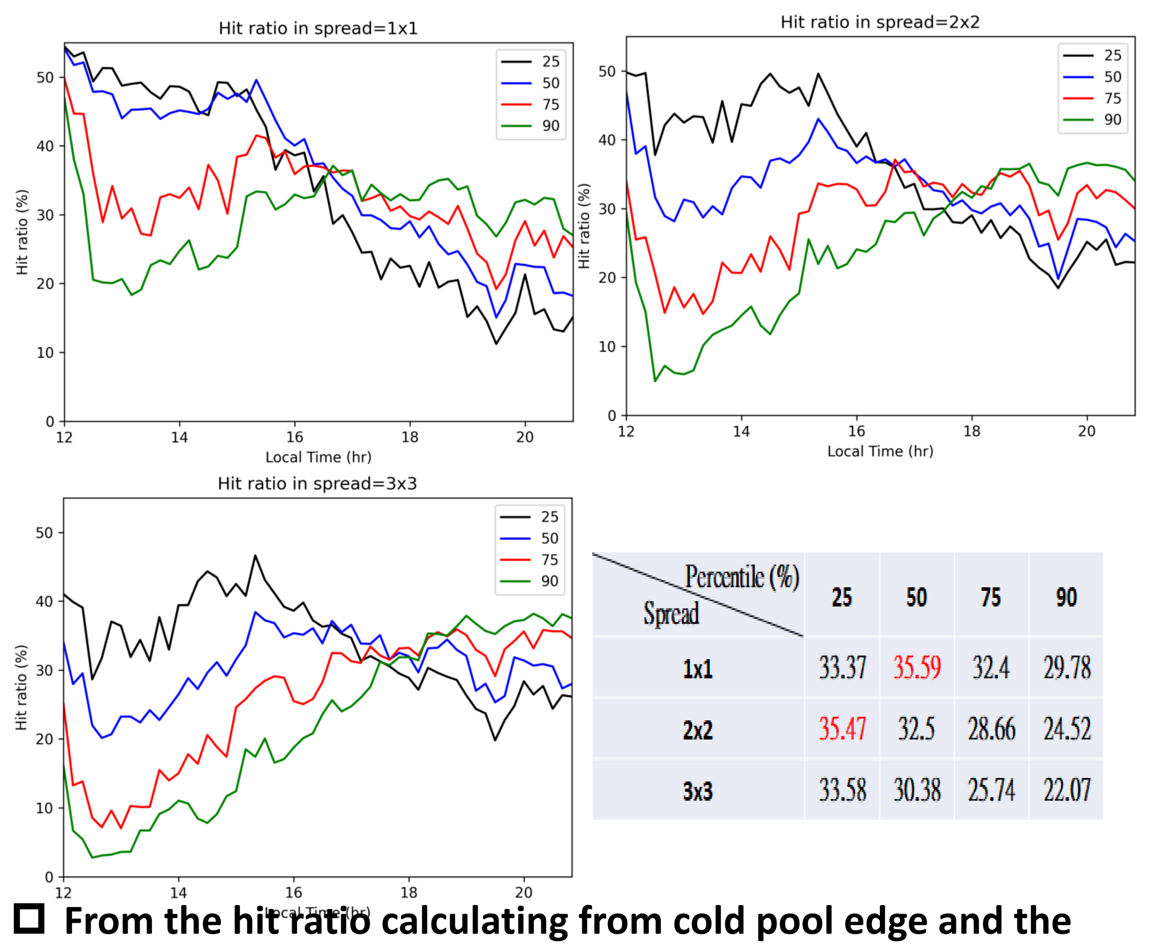
Sensitivity test of different feature size



- With smaller spatial size, the cold pool intensity distribution(blue) more fitting to the convergence zone(gold) and some rainfall region(red).
- With smaller object size and spread ratio, the cold pool matches the convergence zone more closely.



- From the vertical structure, it shows that the cold pool can effect the inflow regime and trigger the convection earlier than the topography lifting.



Spread \ Percentile (%)	25	50	75	90
1x1	33.37	35.59	32.4	29.78
2x2	35.47	32.5	28.66	24.52
3x3	33.58	30.38	25.74	22.07

- From the hit ratio calculating from cold pool edge and the convergence overlap's count, it shows that the highest ratio is at small feature domain(about 15 km), which is occurred in the afternoon(from 12 to 16 LST).

Summary & Future work

- With considering precipitation object size to modify the spatial region for calculating $\overline{\theta_p}$, the cold pool distribution is more reasonable under small scale of convection and topography.
- Here is the first step to define more reasonable cold pool edge. Next we will use this method to discuss the interaction between the convection and cold pool over complex topography.

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