200m Resolution Numerical Weather CPAS Model With Data Assimilation Cycling Capability

Man Cheung Alex, Li[1]

1 Clustertech Limit, Units 211 - 213, Lakeside 1, No. 8 Science Park West Avenue, Hong Kong Science Park, N.T., Hong Kong

Abstract

The latest version of CPAS-JEDI has been successfully extended to incorporate data assimilation (DA) cycling in its numerical weather prediction (NWP) model with regional mesh refinement down to 200m resolution. Studying the cold front scenario in late December 2023, it is demonstrated that the DA-updated fields from CPAS-JEDI can spatially resolve temperature and wind profiles, and correctly reflect the terrain in Hong Kong territories. The capability to conduct realistic and on-time atmospheric simulations with such high resolution refinement is beneficial to the urban design and development such that CPAS-JEDI can serve sub-km weather forecasting and potentially provide driving fields for urban building modeling and operational decisions.

Introduction

The ClusterTech Platform for Atmospheric Simulation (CPAS), involving Customizable Unstructured Mesh Generation (CUMG) and Hierarchical Time-Stepping (HTS), has been developed to provide accurate forecasts towards regions of scales down to hundreds of meters. Meanwhile, Joint Effort for Data assimilation Integration (JEDI) is a multi-component software package that provides essential functions to run DA applications for atmospheric simulations. Its compatibility with variable resolution simulations makes itself adaptable to CPAS applications. With the successful integration with JEDI, CPAS is evolving into a fully operational and self-contained NWP model without any dependence on the output of other NWP models. In 1km-200m scale, the terrain is well resolved, and have impacts on atmospheric simulations. To examine CPAS-JEDI's capability in this scale, we performed experiments on a cold front scenario in late December 2023 using a mesh of various regional refinements as shown in Figure 1. Figure 2 illustrates CPAS-JEDI's DA cycling workflow. The experiment results are presented in Figure 3. And the output temperature and wind fields are shown in Figure 4 to demonstrate that CPAS-JEDI's capability to resolve local variations of atmospheric variables.

Mesh design

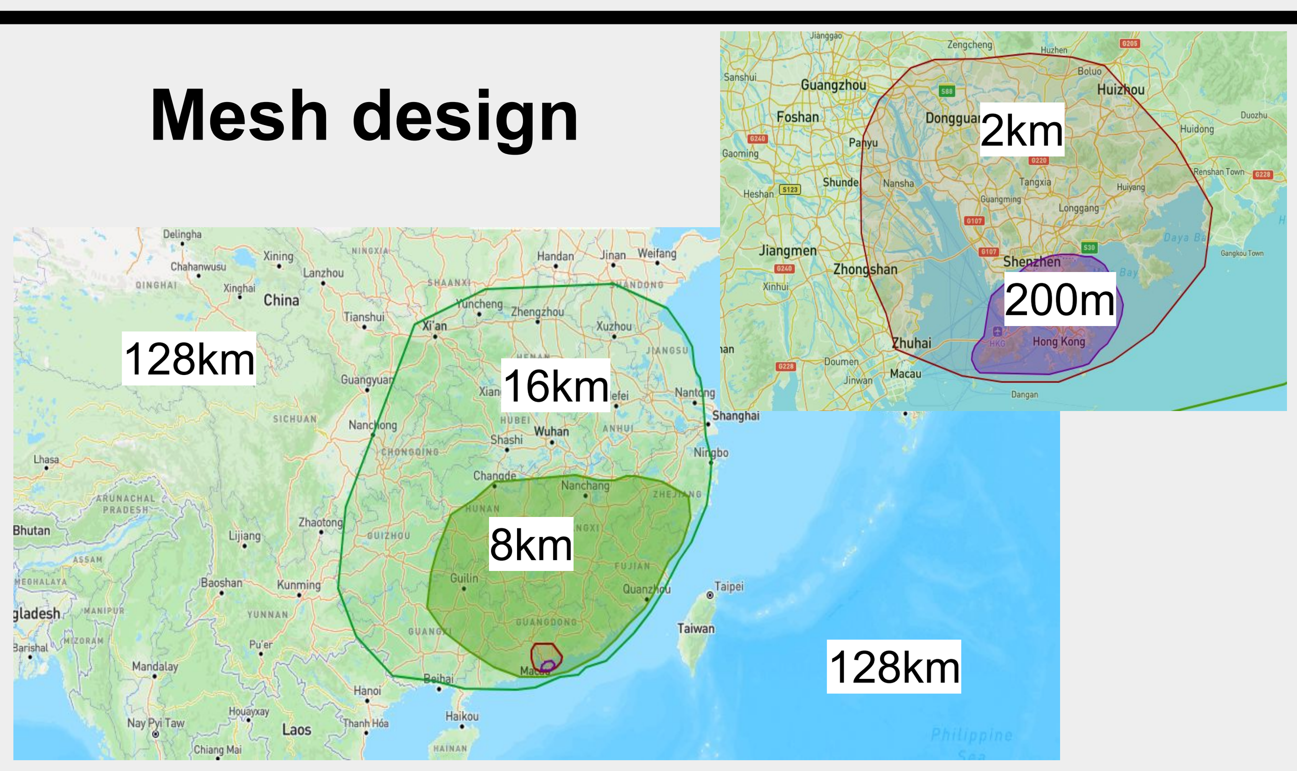

Figure 1. The mesh design. The area coverage of the refinement mesh grid is listed as follows:

- **200m:** Hong Kong SAR's territories
- **2km**: neighboring region around Hong Kong SAR
- **8km**: South China
- **16km**: A larger area including the cold-front forming region
- **128km**: the rest of the globe

DA cycling workflow

1. run JEDI DA with the background field and observation data at T=6*n (i.e., the nth DA cycle) to generate an analysis field;
2. run CPAS simulation with the analysis field up to T=6*(n+1) to generate the background field for the (n+1)th DA cycle;
3. use the CPAS simulation at T=6*(n+1) as the background field of the (n+1)th DA cycle;
4. repeat Steps 1-3 up to the last DA cycle.

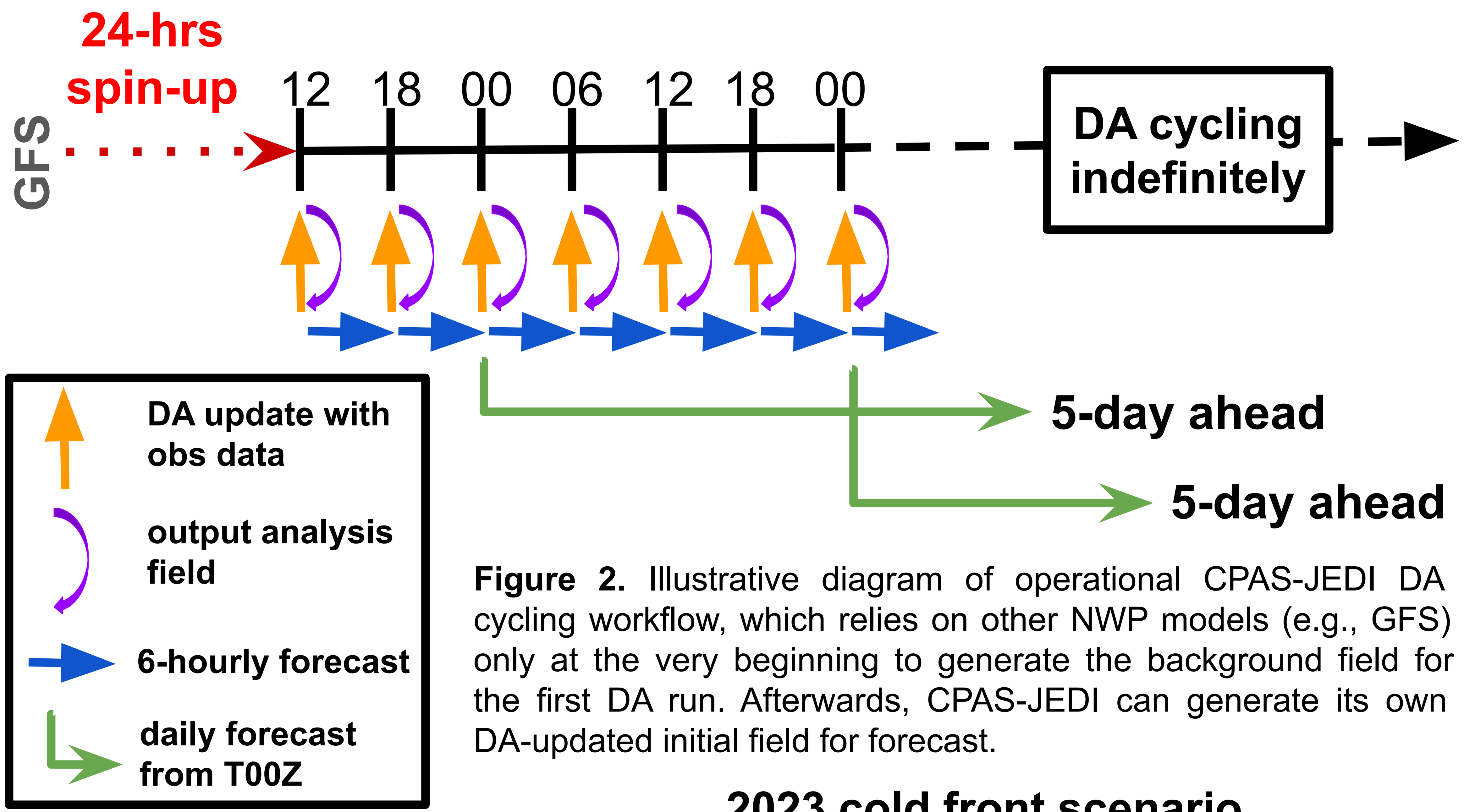

Figure 2. Illustrative diagram of operational CPAS-JEDI DA cycling workflow, which relies on other NWP models (e.g., GFS) only at the very beginning to generate the background field for the first DA run. Afterwards, CPAS-JEDI can generate its own DA-updated initial field for forecast.

2023 cold front scenario

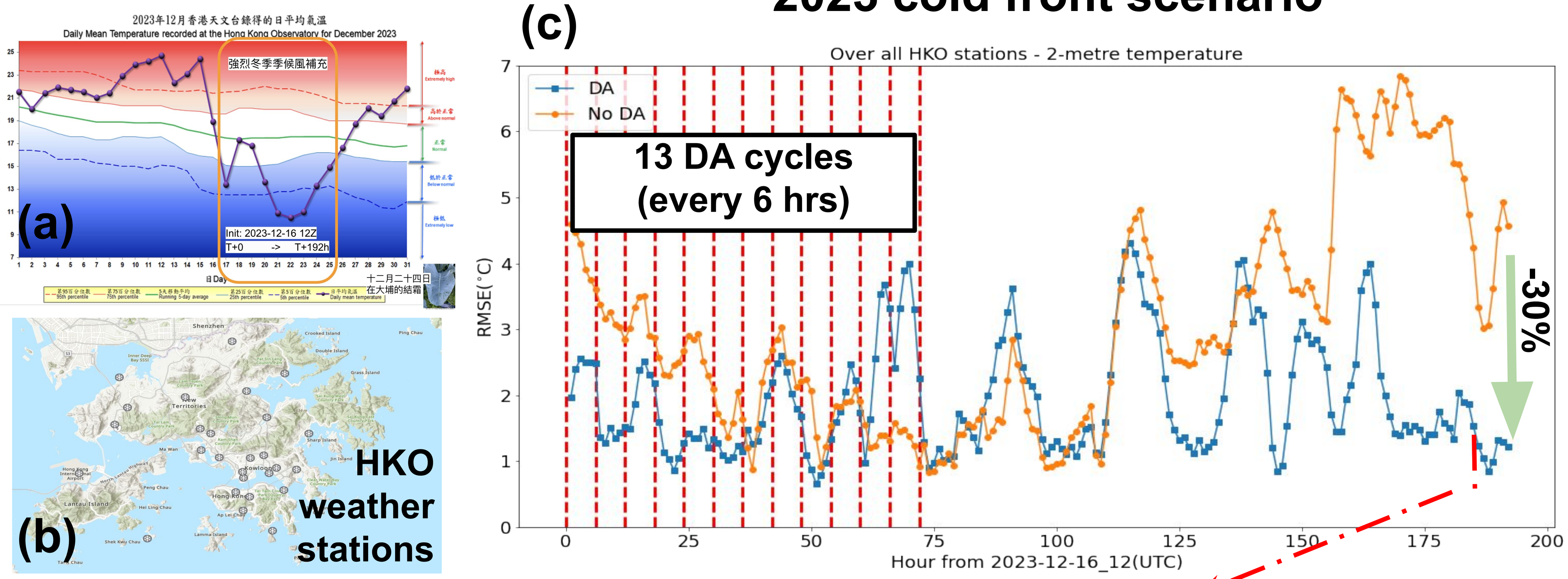

Figure 3. (a) Hong Kong daily mean temperatures in December 2023. **(b)** HKO weather station locations. **(c)** Times series (from 2023-12-16T12Z to 2023-12-24T12Z) of RMSEs of 2m temperature forecasts over 34 available HKO stations; the blue curve corresponds to the forecast with DA cycling and the orange curve to that without DA; the red dashed lines mark the DA cycle times, in which CPAS-JEDI executed DA with conventional and satellite data to update a model field (produce an analysis field) for the following simulation run. For the cold front scenario, the RMSE of 5-day ahead forecast from the DA cycling was reduced by **30%** regarding the No-DA forecasting (No DA).

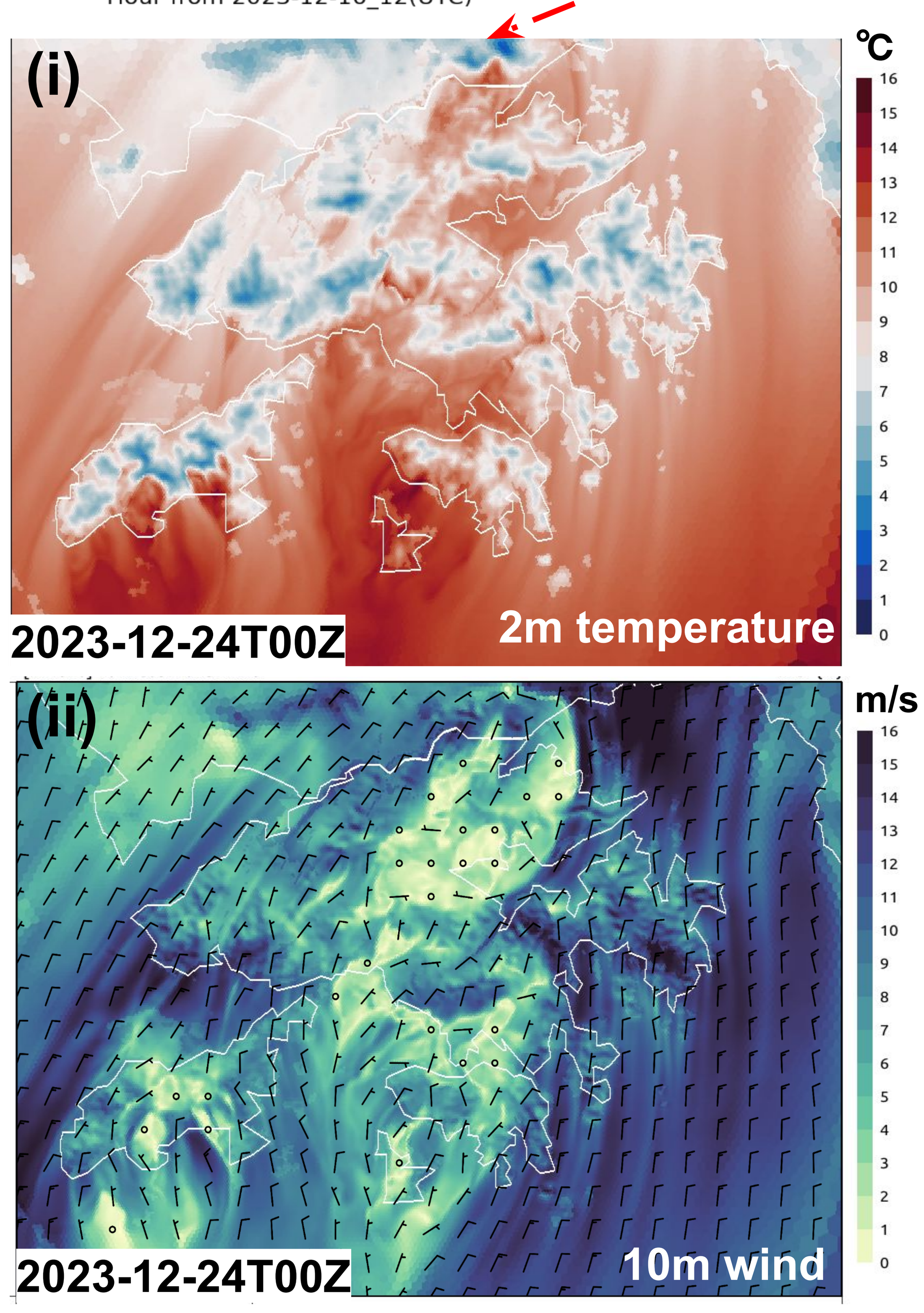

Figure 4. (i) Zoom-in of 2m temperature field and **(ii)** 10m wind field from CPAS-JEDI over Hong Kong territories with 200m resolution refinement at **2023-12-24T00Z** (i.e., 8:00am, 24th December 2023 HK) time snapshot. The temperature and wind speed variations are resolved and consistent with HK's terrain.

CPAS-JEDI Achievements & Conclusion

The DA cycling experiments for the 2023 cold front scenario using the 200m regional refinement mesh over HK territories demonstrate that CPAS-JEDI can (1) provide accurate temperature forecasts over the 200m refinement region, (2) carry out operational forecasts with DA cycling, and (3) output fields of 200m regional refinement which resolves surface temperature variations and wind speed profile that correctly reflect the terrain. Given such refinement, the CPAS-JEDI has the potential to provide regional forecasts of sub-km scales on temperature and wind fields. These forecasted fields may be used as driving fields for aerodynamic models, to guide smart-building operations, and help future development of low-altitude economy, etc.