180

Implementation of Terrain Resolving Component by Immersed Boundary Method for Variational Doppler Radar Analysis System (VDRAS)

Sheng-Lun Tai[1], Yu-Chieng Liou[1], Juanzhen Sun[2], Shao-Fan, Chang[1]

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

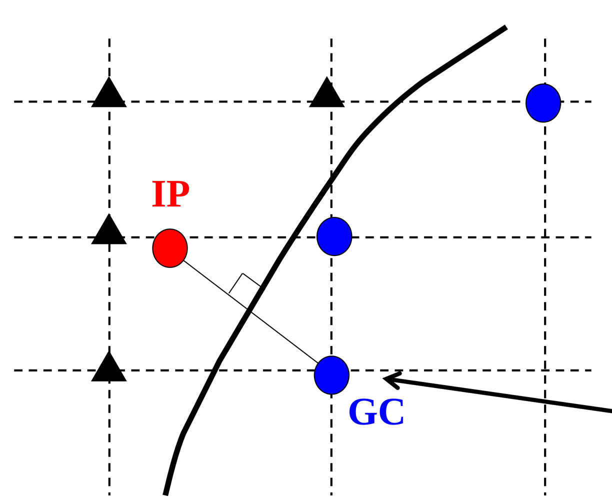
[2]National Center for Atmospheric Research, Boulder, Colorado, USA

Introduction

- A 4DVAR Doppler radar retrieval system for high-resolution and rapid updated analysis. Installed in more than 20 sites since 1998. (Sun and Crook, 1997)
- Cloud model inside the system has no ability to resolve terrain.
- Improve the accuracy of analysis even short-term Quantitative Precipitation Forecast (QPF) by implementing terrain resolving ability for VDRAS.

Ghost-cell immersed boundary method (GCIBM)

- Tseng and Ferziger (2003)
- Ghost-cell: first grid point under terrain surface (immersed boundary).
- Imposing terrain boundary condition implicitly by updating ghost-cell value.
- Update every time step in model integration. Terrain effect gradually obtained.
- Variables updated: U, V, W, θ, qt and qr.



$$w = u\frac{dh}{dx} + v\frac{dh}{dy}$$

Fig. 1. Schematic of domain with an immersed boundary. Triangle points (▲) represent grid points in the flow region, Blue circle points (**GC**) locate the ghost-cells and red circle points are the image points (**IP**) of ghost cells. The line connected with **IP** and **GC** is perpendicular to the immersed boundary.

2-D linear mountain wave simulation

- Simulated for comparisons with the available analytic solution (Smith,1980).
- Isothermal atmosphere (dT/dZ = 0), T = 250 K. Bell-shaped mountain.
- Parameters: wind speed = 20 ms^{-1}, terrain half-width = 10 km, max. height = 1 m.
- Model resolutions: △x = 2 km, △z = 200 m.

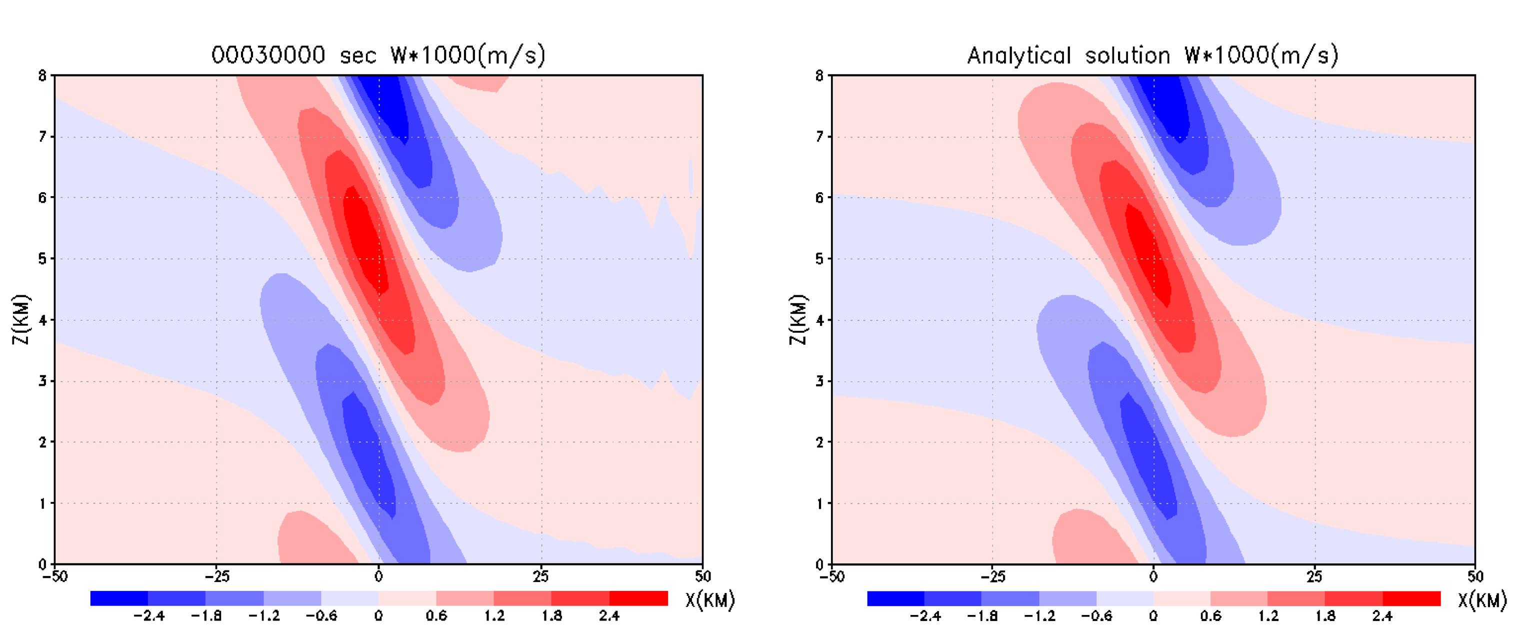


Fig. 2. The vertical velocity field of 2-D linear mountain wave. (Left): Result by model simulation at 30000 seconds (Ut/a= 60). (Right): Analytical solution ; both the magnitudes have been amplified by 1000.

Parallel forecast with WRF model

- Both models are initialized by the same sounding profile (squall line).
- Microphysic scheme: Kessler (warm rain process).
- Terrain: half-width = 10 km, maximum height = 2 km.
- VDRAS cloud model resolutions: △x = 1 km, △z = 250 m. (161 x 141 x 50 grids)

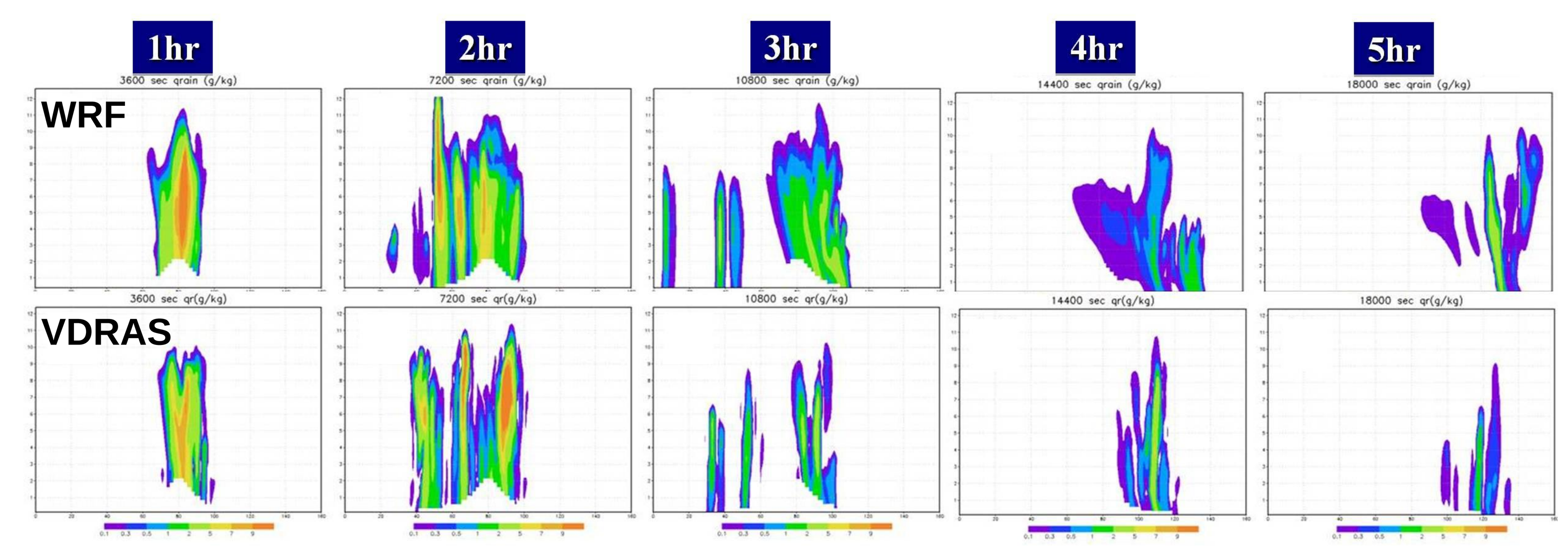


Fig. 3. Vertical cross sections (along Y=71) of rainwater mixing ratio forecast results: Upper panels represent WRF model forecasts from 1th to 5th hour; lower panels are from modified VDRAS cloud model.

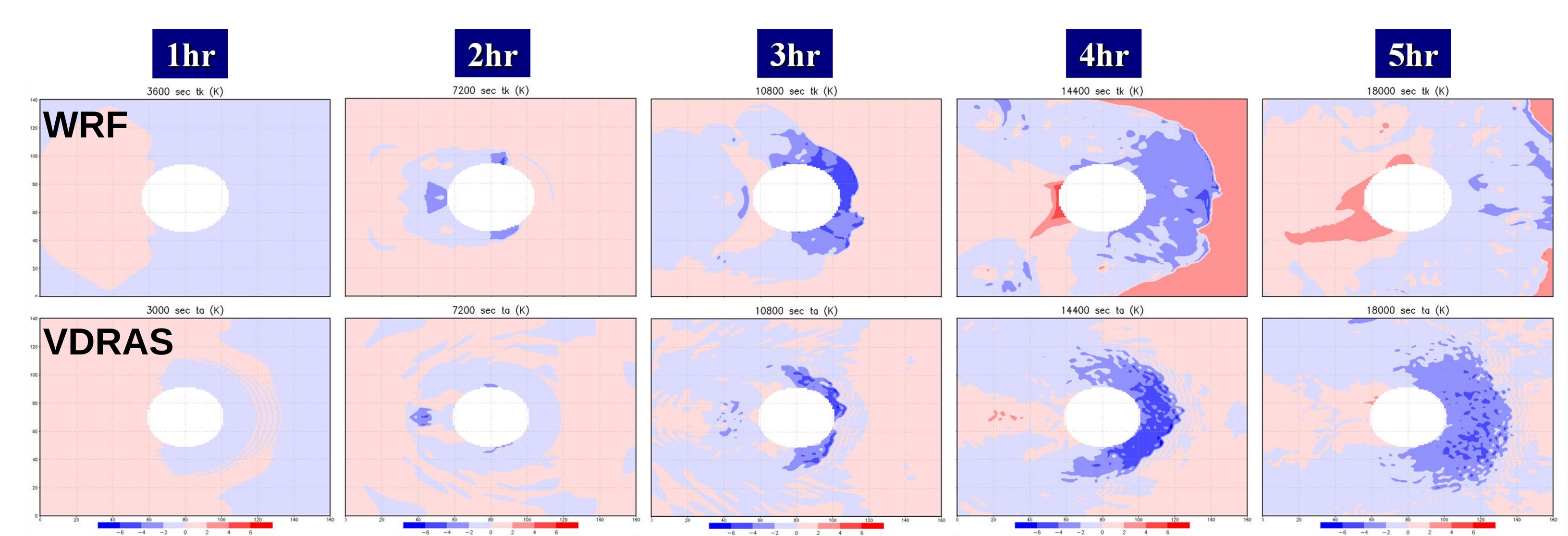


Fig. 4. The temperature perturbation forecast results at Z=5 level: Upper panels represent WRF model forecasts from 1th to 5th hour; lower panels are from modified VDRAS cloud model.

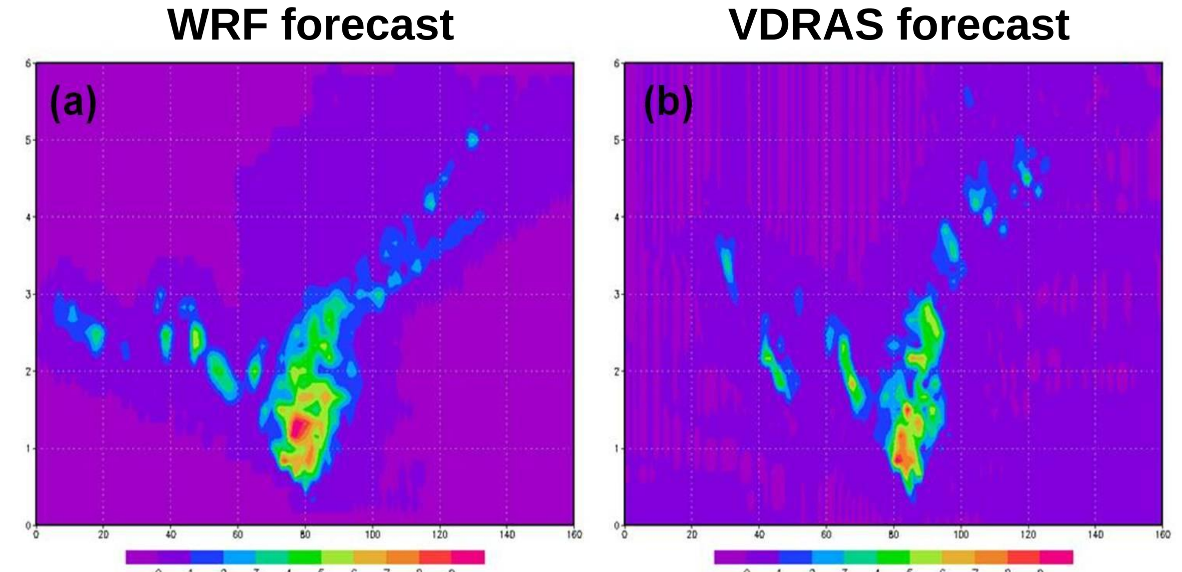


Fig. 5. The Hovmoller diagram of forecast rainwater mixing ratio along Y=71 at Z=10 level by (a) WRF model and (b) VDRAS cloud model. The Y-axis ranges from 0 to 6 hours.

- VDRAS cloud model with IBM could generate similar convection evolution as WRF model.
- Cold pool propagation dominates convection development.

OSSE: data assimilation experiment

- Verification for adjoint model and assimilation scheme.
- Virtual radial wind and rainwater mixing ratio from WRF are assimilated (full domain coverage).
- Assimilation strategy and experiment design:

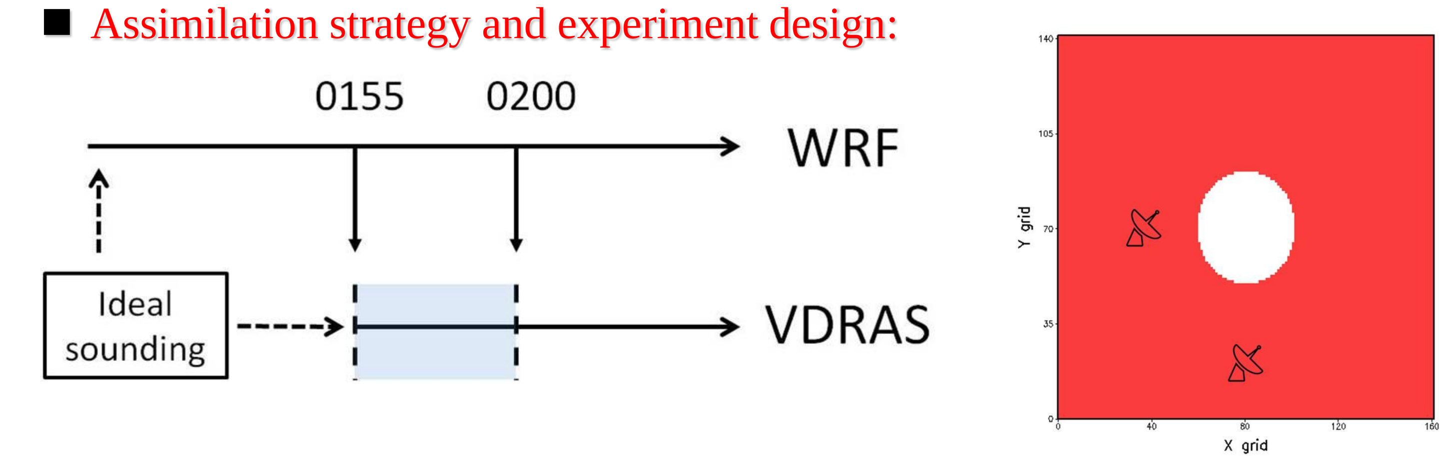


Fig. 6. Assimilation strategy (left) and model domain with radar locations (right) for the OSSE. Two sets of radar data are assimilated in the assimilation cycle (light blue).

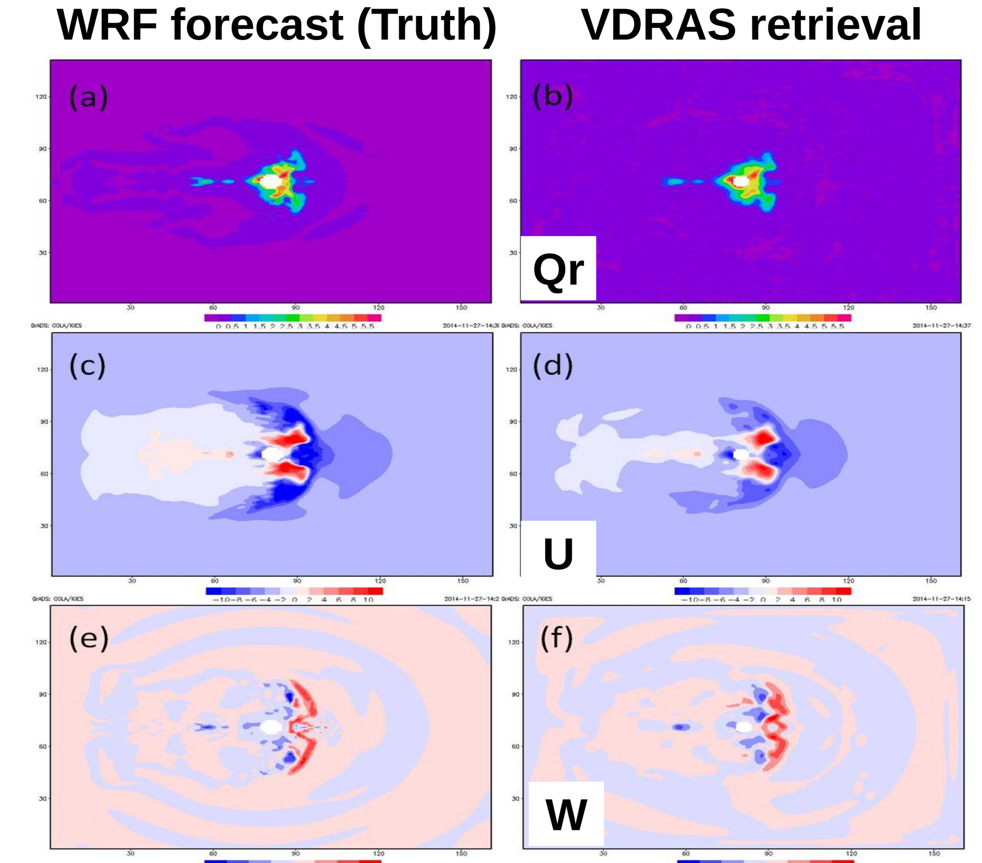


Fig. 7. WRF forecasts (a,c,e) and VDRAS retrievals (b,d,f) at 1875 meter height level. (a), (b): rainwater mixing ratio (gkg^{-1});(c), (d): U-wind (ms^{-1}); (e), (f): Vertical velocity (ms^{-1})

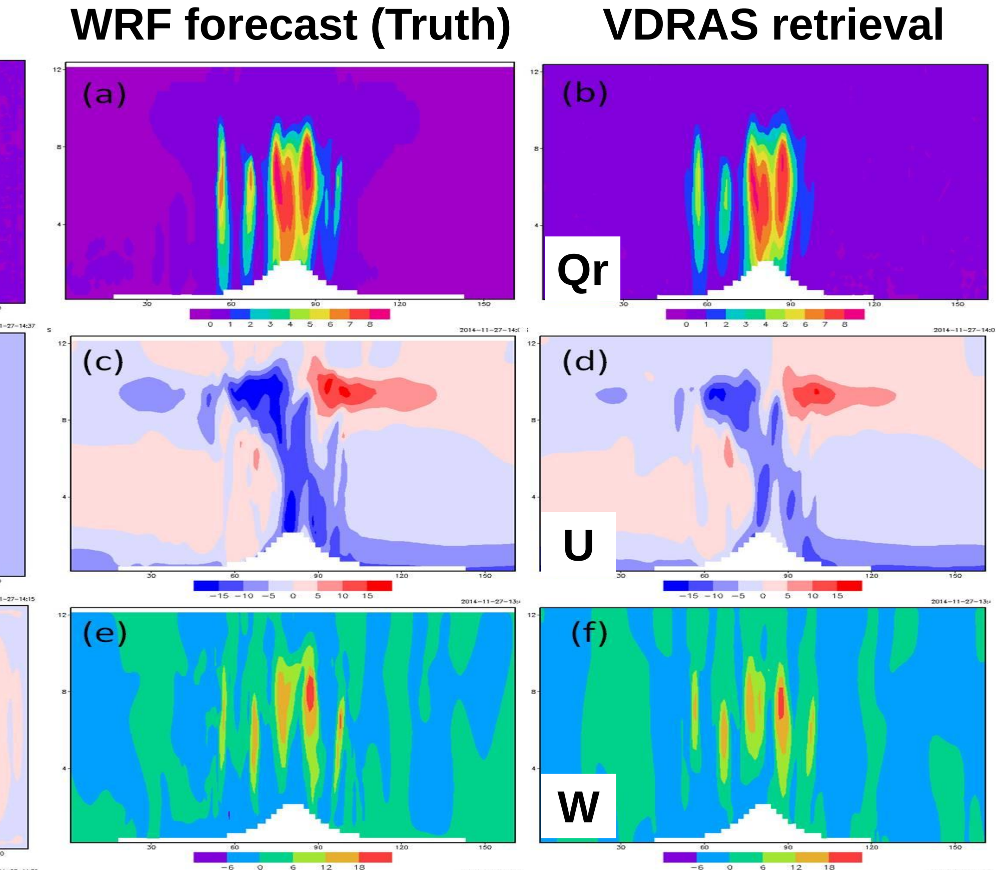


Fig. 8. Vertical cross sections (along Y=71) for WRF forecasts (a,c,e) and VDRAS retrievals (b,d,f). (a), (b) : rainwater mixing ratio (gkg^{-1}); (c), (d) : U-wind (ms^{-1}); (e), (f) : Vertical velocity (ms^{-1})

- Radar data successfully assimilated into model.
- Dynamic variables and microphysic variable corrected by observations.

Summary and future work

- Parallel forecast shown the terrain-resolving capability of modified forward model.
- OSSE results display the surprising performance of assimilation scheme, and proved the completeness of modified adjoint model.
- Application to real cases with terrain-interacted convections, which can provide convective-scale analysis and even short-term QPF.

References and acknowledgments

Sun, J. and N. A. Crook, 1997: Dynamic and microphysical retrieval from Doppler radar observations using a cloud model and its adjoint. Part I: Model development and simulated data experiments. *J. Atmos. Sci.*, **54**, 1642–1661.

Tseng, Y., and J. Ferziger, 2003: A ghost-cell immersed boundary method for flow in complex geometry. *J. Comput. Phys.*, **192**, 593–623.

This research is sponsored by Central Weather Bureau of Taiwan, under Grant MOTC-CWB-103-M-06.