Comparing the Partial Cycling and Continuous Cycling Data Assimilation Strategies in a High-Resolution Regional Forecast System

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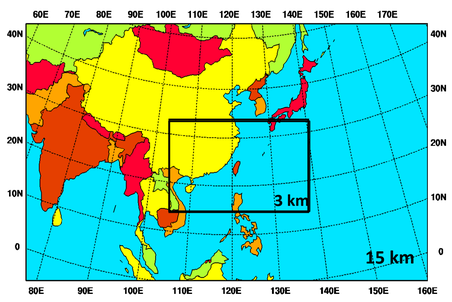
Introduction

The Central Weather Administration (CWA) of Taiwan operates a regional deterministic NWP system named WRFD, which is developed based on the Advanced Research Weather Research and Forecasting (WRF-ARW) model and the WRF Data Assimilation (WRFDA) system. The initial condition of WRFD is generated using a so-called partial cycling (PC) strategy where each run is independently initialized from the NCEP Global Forecast System (GFS) analysis. In addition, a "blending" technique is used in WRFD to replace the large-scale characteristics of the WRFDA regional analysis with the GFS analysis. This PC strategy combined with blending takes advantage of the high-quality global model analysis from NCEP GFS while maintaining some mesoscale information from the WRFD, which has been quite successful at CWA in operationally producing skillful regional forecast guidance. However, this strategy largely limits regional DA development via outsourcing from the global analysis.

To seek for a potential alternative, this study tested a continuous cycling (CC) strategy with blending where blending is only used prior to the deterministic forecast, similar to the approach used in Schwartz et al. (2022). We then compare the forecast performance of the WRFD resulting from the abovementioned PC and CC strategies and discuss their advantages and disadvantages in various aspects of the regional forecast.

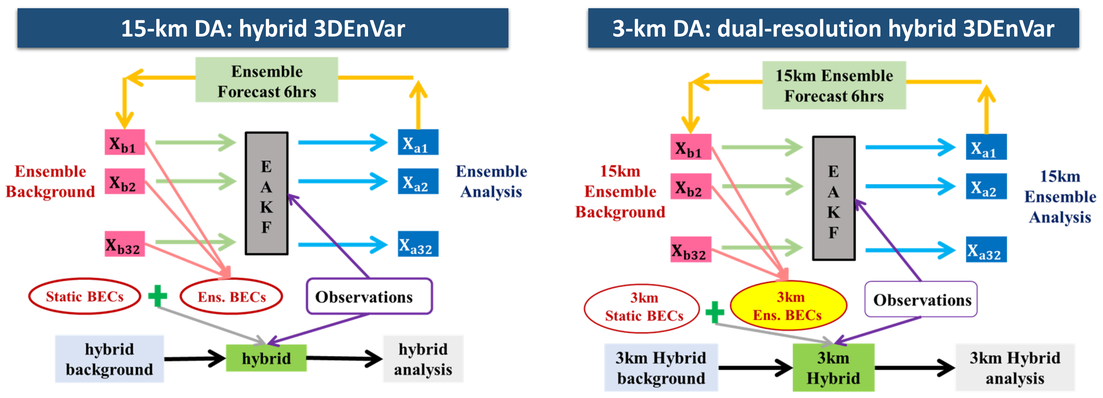
Current Status of the CWA WRFD

A. Model Configuration



- **Model Domain**
  2 nested domains with a horizontal grid spacing of 15-km and 3-km respectively
- **Vertical Levels**
  52 levels (model top at 20 hPa)
- **Model Version**
  WRF v4.4.2 / CWA WRFDA v3.9.1
- **Forecast length**:
  126 hours, 4 times per day

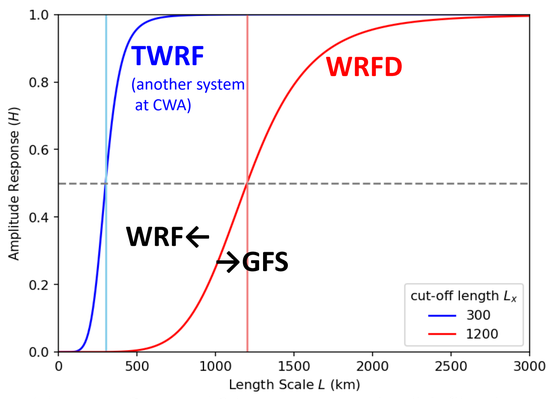
B. Data Assimilation System



- **Assimilated observations include:**
  synoptic observations, ship observations, meteorological terminal aviation weather reports, soundings, airplane reports, buoys, ground-based GPS zenith total delay data, FORMOSAT-7/COSMIC-2 radio occultation data , and wind profiler data (only used in the 15-km domain).

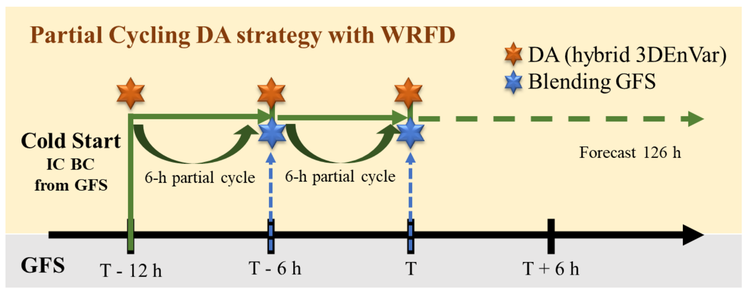
C. Blending with GFS analysis

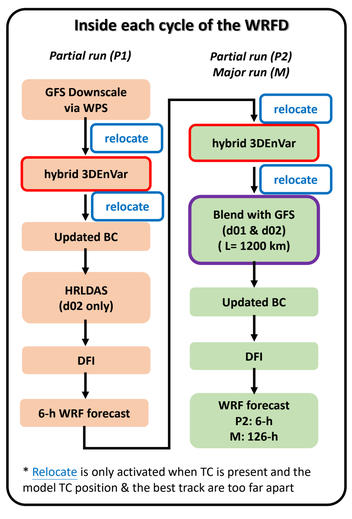
- The primary goal of the blending method is to improve the description of large-scale features in the WRF analysis field.
- In WRFD, a 1200 km cut-off length is used to filter the WRFD and GFS analyses. After filtering, the small-scale features from WRFD (to the left) and the large-scale features from NCEP GFS (to the right) are combined into a new analysis.



A low-pass Raymond 6th order tangent implicit filter is used.

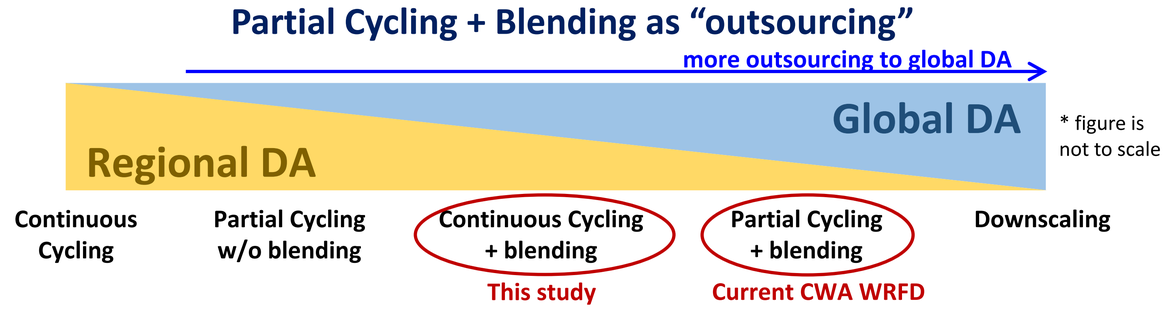
D. Partial Cycling (PC) workflow





- Pros:
  - easy to maintaining, especially for operational NWP center
  - takes advantage of the high-quality global analysis while maintains some mesoscale information from the regional analysis
- Cons:
  - **Not sufficient time for regional DA effect to accumulate; Regional DA effect is largely obstructed by the global analysis**

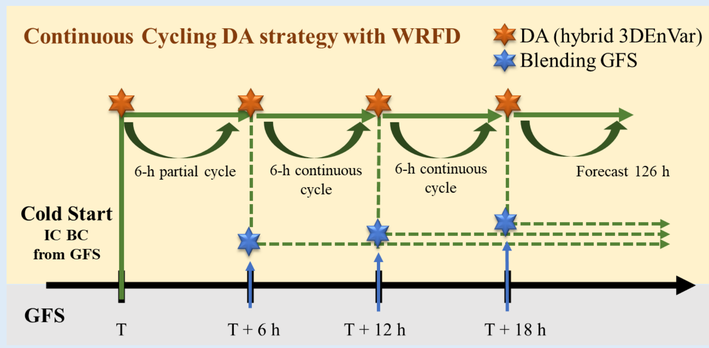
Partial Cycling + Blending as "outsourcing"

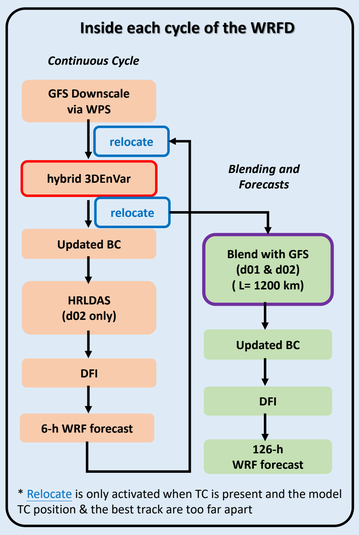


"On one's own":
- Difficult to outperform global DA
- Potential to improve the short-range high-res forecast
- Possibly have more balanced analysis
- Preserve full freedom to develop/study regional DA

"Outsourcing":
- Easy to achieve reasonably good performance, especially in longer-range, large-scale forecast
- Reduce the requirement of skillful regional DA
- Easy to maintain (both for operation and research)
- Difficult to see the impact of regional DA

New Strategy: "Continuous Cycling + Blending"





- Allow sufficient time to accumulate regional DA effect
- Minimize the "memory" from the global model

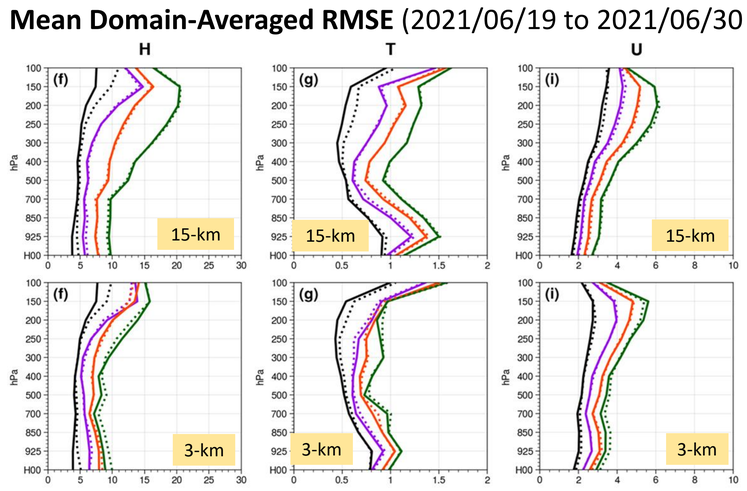
➢ **The ultimate goal of this new CC + blending strategy is to improve the QPF of the CWA WRFD 3-km domain.**

Exp.	DA Cycling Strategy	Blending	WRF/WRFDA Version	DA Method
PC	Partial Cycling	After the 2nd and 3rd DA	4.4.2/4.4.2	hybrid 3DEnVar
CC	Continuously Cycling	Before extended forecast (independent from DA cycling)	4.4.2/4.4.2	hybrid 3DEnVar

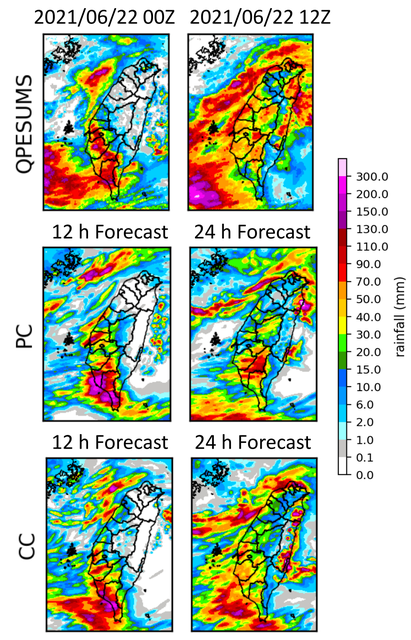
- CC spin up period: 2022/06/15 12Z to 2022/06/18 18Z, with 6-hr cycling
- Testing periods:
  - 2022/06/19 00Z to 2022/06/30 12Z , total 24 forecast cases (only at 00Z and 12Z)
  - CC keeps 6-hr cycling but makes 72-hr forecasts only at 00Z and 12Z
  - Assimilated observations: the same as the operational WRFD

Results

Mean Domain-Averaged RMSE (2021/06/19 to 2021/06/30)

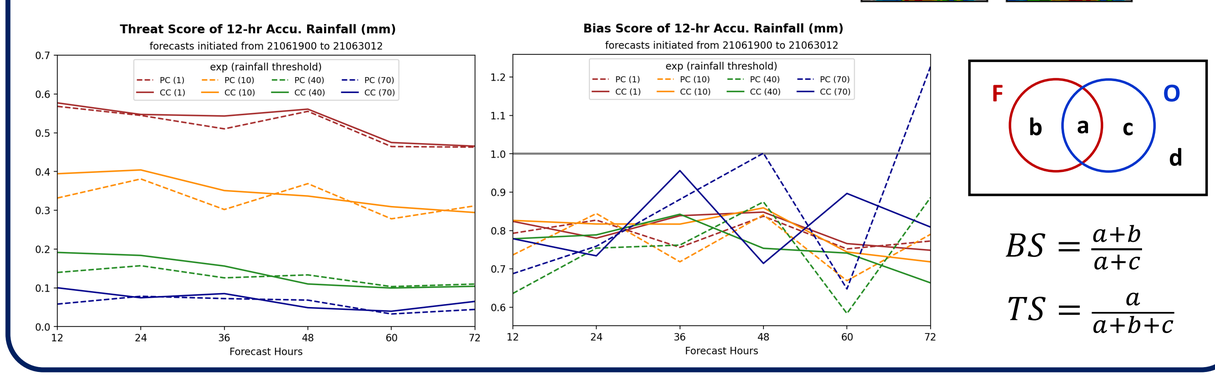


Mei-yu Frontal Cases



Upper: When verified against ECMWF analysis, PC performance is slightly better than CC up to 72 hour forecasts.

Right Panel: In this case, some improvements on precipitation forecast are evident in the CC strategy.



Conclusion

- This new "continuous cycling + blending" (CC) strategy seems to be a competitive alternative to the operational "partial cycling + blending" (PC) strategy.
- CC strategy has slightly worse performance in terms of domain-averaged synoptic forecast skill. Nevertheless, CC strategy shows better short-term (up to ~24 hours) precipitation forecast!

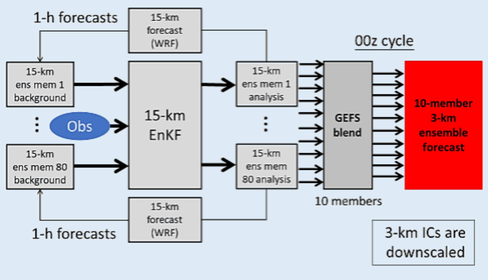
Future Work

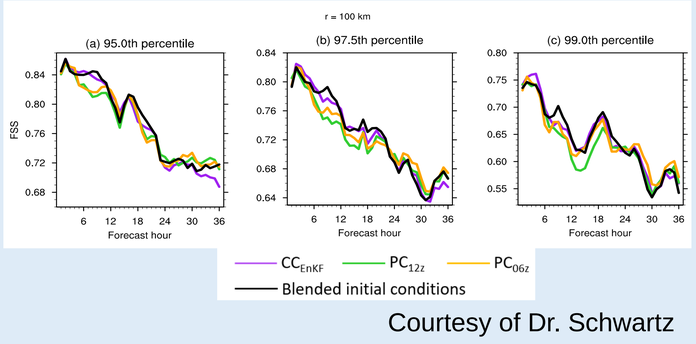
- Set up a parallel run using the CC strategy to systematically evaluate its long-term performance with different types of weather systems and compare it to the PC strategy, which helps CWA decide whether to switch to the CC strategy in operation.
- Continue to improve the hybrid 3DEnVar DA of the CWA WRF system (e.g., assimilate more satellite observations, investigate the proper blending cut-off length for each domain, etc.)

Inspirations from a Recent Study over the CONUS Domain

Continuous cycling and blending

- 80-member continuously cycling EnKF **with blending**
  - 15-km EnKF DA





Courtesy of Dr. Schwartz

- CC has highest FSS score in 1–18-h forecasts
- PC shows superior performance after 18-h forecast (need some time to spin up)
- Combining blending procedure with CC strategy yielded 18–36-h forecasts as good as those initialized from PC analyses

Reference

Schwartz, C. S., J. Poterjoy, J. R. Carley, D. C. Dowell, G. S. Romine, and K. Ide, 2022: Comparing Partial and Continuously Cycling Ensemble Kalman Filter Data Assimilation Systems for Convection-Allowing Ensemble Forecast Initialization. *Wea. Forecasting*, **37**, 85–112, https://doi.org/10.1175/WAF-D-21-0069.1.