Evaluation of an Ensemble Partial Cycling Framework for Use in the Regional Ensemble Prediction System at the Central Weather Administration of Taiwan

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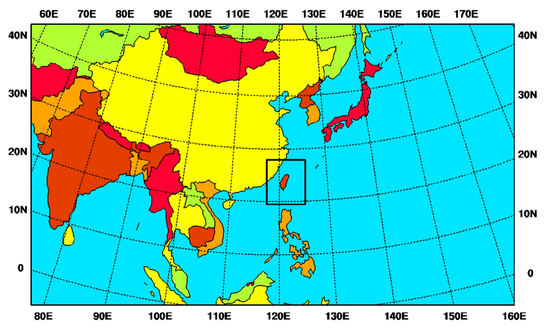
Overview

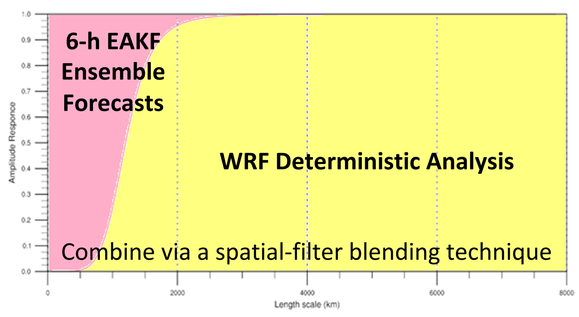
The Central Weather Administration (CWA) of Taiwan is responsible for issuing official weather forecasts and warnings of hazardous weather. For this purpose, CWA has been developing and operating global and regional numerical weather prediction (NWP) systems and providing both deterministic and ensemble forecast products as the forecast guidance. With the goal to move toward a more strongly linked global and regional NWP system, efforts have been made to connect the two systems. This study proposes a new regional ensemble initialization method named Ensemble Partial Cycling (EnPC) to generate regional ensemble initial conditions for CWA WRF-based regional Ensemble Prediction System (WEPS). The EnPC method can be conceptually regarded as a combination of the Ensemble of Data Assimilation and partial cycling approaches. Our early results show that this new method is superior to the method that is adopted in the current operational WEPS based on an Ensemble Adjustment Kalman Filter (EAKF) data assimilation.

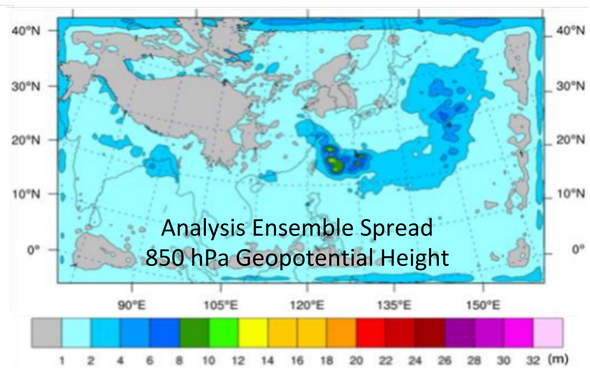
Current Status of WEPS and Known Issue with IC



Ensemble Size	20
Initial Perturbations	Blend EAKF short-range ensemble forecast With WRF deterministic analysis
Boundary Perturbations	NCEP GEFS
Number of GEFS Members Used	10 (2 WEPS members share 1 GEFS member)
Model Perturbations	Multi-Physics + Stochastic Kinetic Energy Backscatter (SKEB) + Stochastically Perturbed Physics Tendency (SPPT) + Stochastically Perturbed Parameterizations for Planetary Boundary Layer (SPP_PBL)

- Domain 1/2 grid spacing: 15 km / 3km
- 52 vertical layers with model top at 20 hPa
- Runs 4 times a day (00, 06, 12, 18 UTC)
- Provides 108-h regional ensemble forecasts (3 km forecasts at nested domain via interpolation)

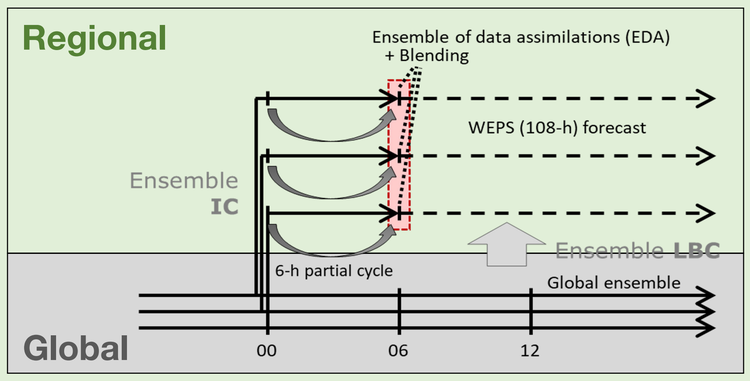




More details please see ***Li et al. (2020)***

A New Framework of WEPS: Ensemble Partial Cycling

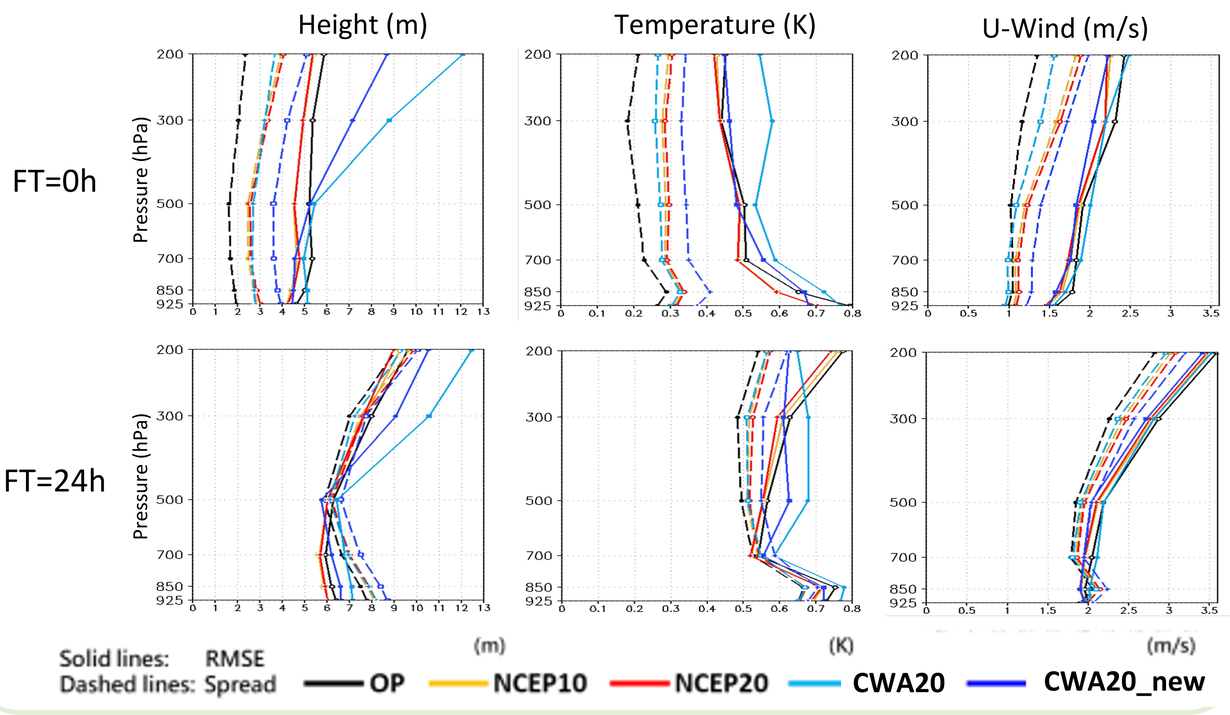
- Inspired by the CWA **partial cycling strategy** & **Ensemble of Data Assimilation (EDA)** framework.
- With EnPC, each WEPS member is initialized by running a partial cycling where ICs come from a global EPS.

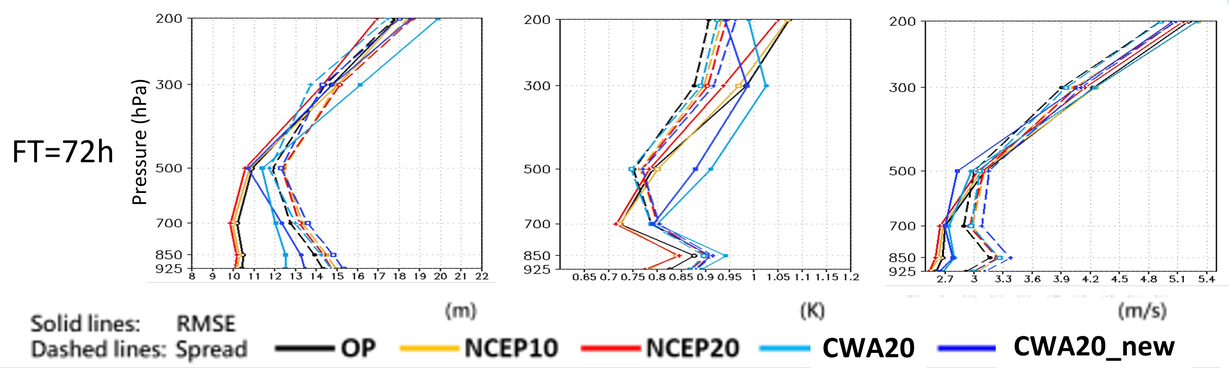


Initial Implementation of WEPS_EnPC

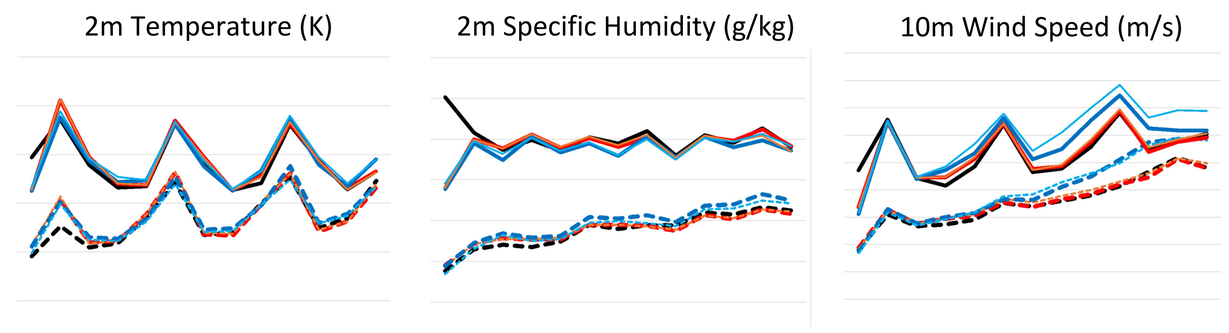
Experiment	Ens. Size	Initial Perturbations	Boundary Perturbations	# of GEFS
OP	20	EAKF blend with WRFD	NCEP GEFS	10 (1-2)
NCEP10	20	***EnPC*** : IC from NCEP GEFS	NCEP GEFS	10 (1-2)
NCEP20	20	***EnPC*** : IC from NCEP GEFS	NCEP GEFS	20 (1-1)
CWA20	20	***EnPC*** : IC from CWA TGFS EPS	CWA TGFS EPS	20 (1-1)

Domain-Averaged Verification Against ECMWF Analysis (Domain 1)

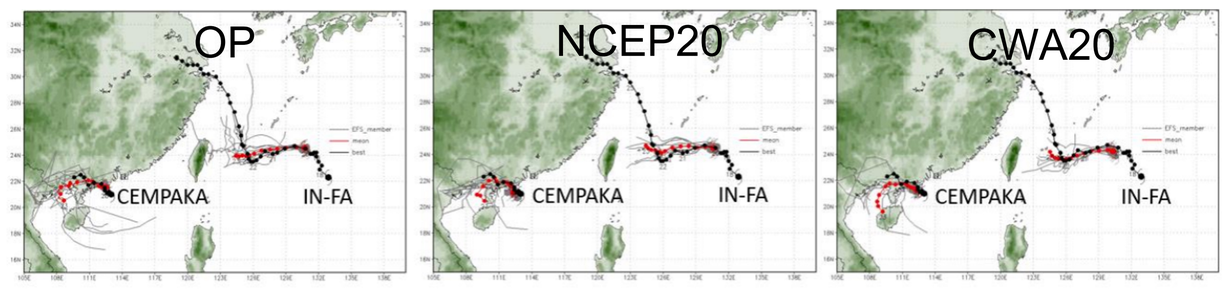




Domain-Averaged Verification Against CWA Ground Station Obs (Domain 2)



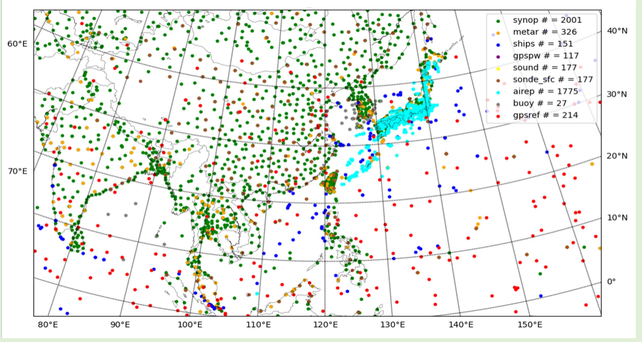
Typhoon Track Forecasts (Domain 1)



See ***Lien et al. (2023)***

Recent Development on WEPS EnPC

Observations assimilated in d01 of WEPS

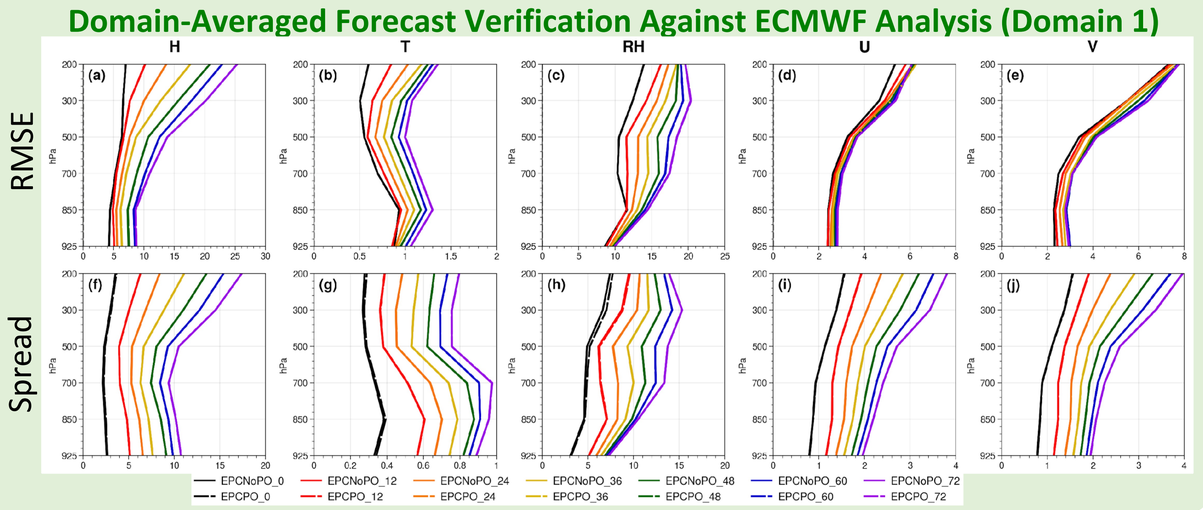


Include "***perturbed observations***" to EnPC (closer to the original EDA idea)

Experiment	Obs assimilated	Perturbed
EnPC_NoPO	CONV + RO	No
EnPC_PO	CONV + RO	Yes

For RO refractivity observations, perturbations are vertically correlated.

Domain-Averaged Forecast Verification Against ECMWF Analysis (Domain 1)



Conclusion

- **The new EnPC framework that combines the partial cycling strategy and EDA approach has been successfully implemented for the CWA WEPS.**
- **WEPS initialized via EnPC mitigates several issues in the current OP:**
  - Insufficient spread due to lack of initial large-scale perturbations: *improved spread*
  - Dependency on EAKF (a separate system to maintain): *removed*
  - Dependency on external data (NCEP GEFS): *could be replaced by CWA TGFS EPS*
  - Spin-up issue in WEPS d02: *d02 is also initialized via EnPC as opposed to interpolation*
- **In addition, compared to OP, WEPS initialized via EnPC has shown increased ensemble spread without degrading RMSE, which is encouraging.**

Future Work

- Investigate the impact of using blending or not under the new EnPC framework.
- Revisit the model perturbation setup to find the best combo for WEPS_EnPC.
- Further investigate the EDA approach/configuration in WEPS_EnPC
- Explore the impact of using WEPS_EnPC ensemble forecasts to estimate BEC for the hybrid EnVar of CWA WRF deterministic system.

Reference

- Li, C.-H., J. Berner, J.-S. Hong, C.-T. Fong, and Y.-H. Kuo, 2020: The Taiwan WRF Ensemble Prediction System: Scientific Description, Model-Error Representation and Performance Results, *Asia-Pacific. J. Atmos. Sci*, 56, pp 1-15, https://doi.org/10.1007/s13143-019-00127-8
- Lien, G.-Yu, C.-H. Li, and W.-H. Teng, 2023: Evaluation of a New "Ensemble Partial Cycle" Framework for Use in the Regional Ensemble Prediction System at Central Weather Bureau, *Meteorological Bulletin,* Vol. 58, No. 1, pp 1-18 (In Traditional Chinese, Abstract in English)