ESSD-2021-217
Response to CC1 (Yan Liu)

The authors thank Yan Liu for a thoughtful review of the manuscript. The response for the community comments is as follows.

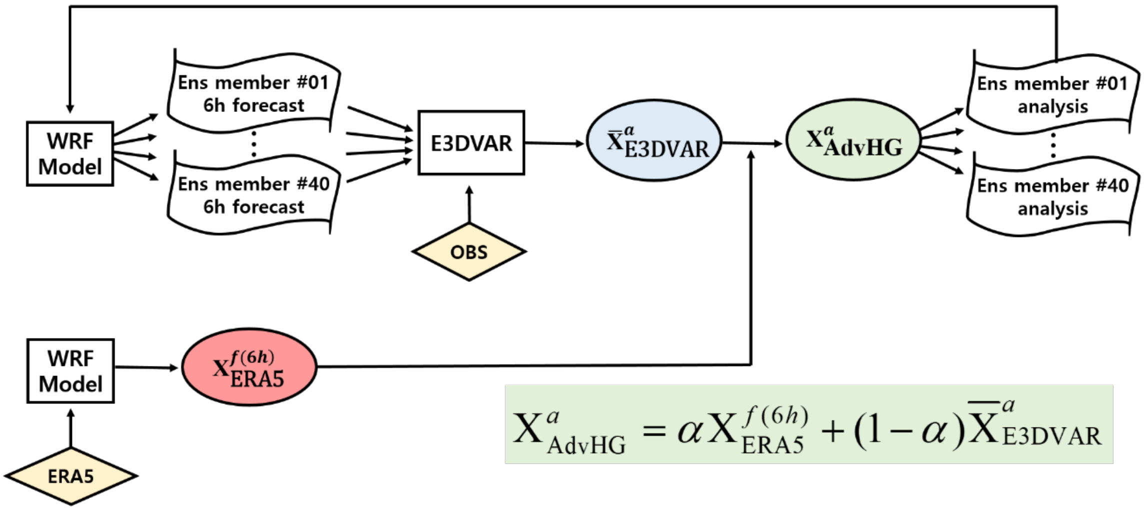
Comments:

The authors have done a lot of works to develop a regional reanalysis system, which are worth publishing. However, the reanalysis is to use more and more reliable archived historical observations than those obtained from real-time numerical forecast analysis, as well as newer and better numerical forecast models and assimilation systems to produce higher-quality analysis. The development of reanalysis system should include two parts, numerical weather prediction system and observations. The authors should present more advantages of EARR compared to other regional reanalysis system. Otherwise, the value of the new regional reanalysis system is less. For example, ERA5 reanalysis has rich satellite data with 25Km resolution, EARR only assimilates conventional observations and Quick scant wind but half domain of ERRA is ocean. ERRA uses ERA5 as initial value and LBC, the forecast has much information of ERA5. It is better to provide some experiments to support the reason why use ERA5 forecast field is better than deterministic analysis in page 7.

Authors' response: Specific responses for Yan Liu's comments are as follows.

A. However, the reanalysis is to use more and more reliable archived historical observations than those obtained from real-time numerical forecast analysis, as well as newer and better numerical forecast models and assimilation systems to produce higher-quality analysis. The development of reanalysis system should include two parts, numerical weather prediction system and observations.

Authors' response: As Yan Liu mentioned, it is essential to present the numerical weather prediction system including a data assimilation method and observations used to develop a reanalysis system. To elucidate the data assimilation system used in East Asia Regional Reanalysis system (EARR), we have added the schematic diagram of the advanced hybrid gain data assimilation method as Figure_rev1 below (Fig. 2 in the revised manuscript).



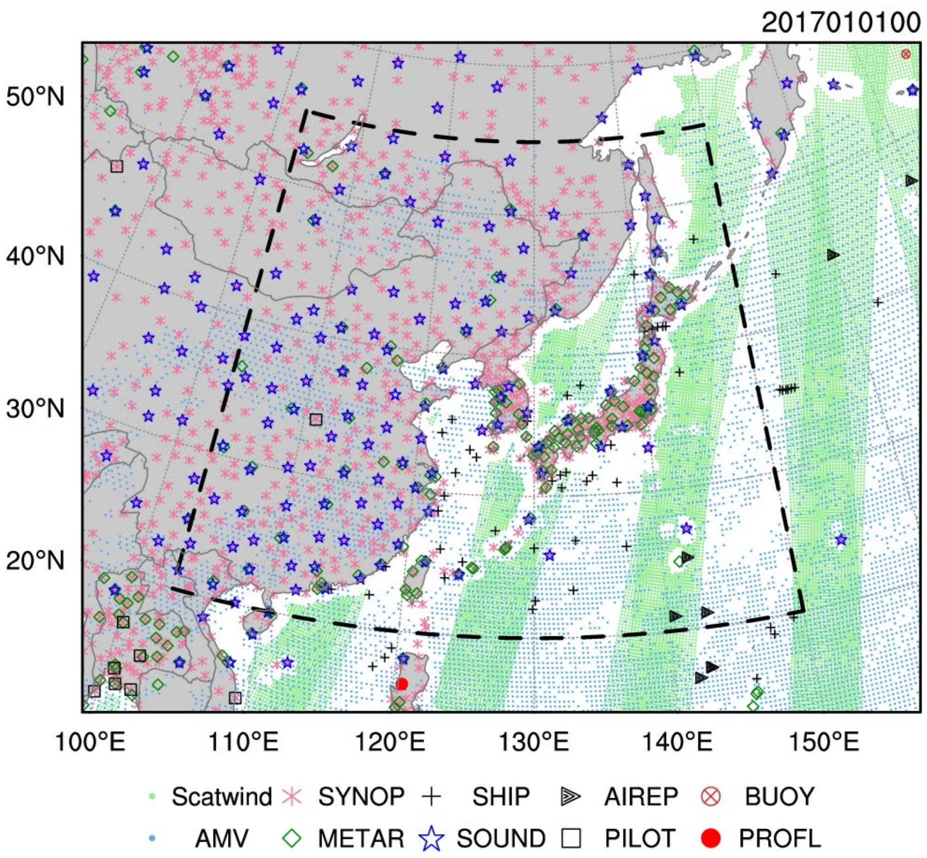
Figure_rev1. The schematic diagram of the advanced hybrid gain data assimilation method in the East Asia regional reanalysis system.

To provide more information on observations assimilated in EARR, we have added details of observations data quality to the revised manuscript as Table 2 (Table_rev1 below). Figure 1 is also modified to show spatial distributions of observations used in this study in the revised manuscript (Figure_rev2 below). Furthermore, the explanation of observation quality control procedure applied to this study is added to section 2.3 in the revised manuscript (underlined below).

Table_rev1. Summary of observations used in this study. The default observation error statistics provided in WRFDA system are used for assimilation in this study. The variables u, v, T, RH, Ps, and TPW denote zonal wind, meridional wind, temperature, relative humidity, surface pressure, and total precipitable water, respectively.

Observations	Descriptions	Variables	Observation errors (depending on vertical levels)
SOUND	Upper-air observation from radiosonde	u, v	1.1-3.3 m/s
		T	1 K
		RH	10-15%
PROFILER	Upper-air wind profile from wind profiler	u, v	2.2-3.2 m/s
PILOT	Upper-air wind profile from pilot balloon or radiosonde	u, v	2.2-3.2 m/s
AIREP	Upper-air wind and temperature from aircraft	u, v	3.6 m/s
		T	1 K
Scatwind	Scatterometer oceanic surface winds	u, v	2.5-3.8 m/s
SHIPS	Surface synoptic observation from ship	u, v	1.1 m/s
		T	2 K
		Ps	1.6 hPa
		RH	10%
SYNOP	Surface synoptic observation from land station	u, v	1.1 m/s
		T	2 K
		Ps	1 hPa
		RH	10%

BUOY	Surface synoptic observation from buoy	u, v	1.4-1.6 m/s
		T	2 K
		Ps	0.9-1 hPa
		RH	10%
GPSPW	Precipitable water vapor from global positioning system (GPS)	TPW	0.2 mm
METAR	Aviation routine weather report from automatic weather station (AWS)	u, v	1.1 m/s
		T	2 K
		Ps	1 hPa
		RH	10%
AMV	Conventional atmospheric motion vector data from geostationary satellite	u, v	2.5-4.5 m/s



Figure_rev2. The East Asia Regional Reanalysis domain with different types of NCEP PrepBUFR observations available for assimilation at 00 UTC on 1st of January in 2017. The black dashed box denotes a verification area.

(L178-196) "The NCEP PrepBUFR [Prepared or QC'd data in BUFR (Binary Universal Form for the Representation of meteorological data) format] conventional observations (global upper air and surface weather observations, NCEP/NWS/NOAA/U.S.DOC 2008) are used every 6 h (00, 06, 12, and 18 UTC) for an assimilation by E3DVAR and AdvHG methods (Fig. 1). The PrepBUFR is the output of the final process for preparing the observations to be assimilated in the different NCEP analyses. For observations, rudimentary multi-platform quality control (QC) and more complex platform-specific QC were conducted (e.g., surface pressure, rawinsonde heights and temperature, wind profiler, aircraft wind and temperature) in NCEP (Keyser 2013). Furthermore, if the innovations (i.e., observation minus background) of some observations are greater than 5 times the observational error, then that observation is rejected during assimilation procedure in this study.

The assimilated observations are as follows: the surface observations (SYNOP, METAR, Ship, and Buoy), radiosonde observation (SOUND), upper-wind report (PILOT), wind profiler, aircraft, atmospheric motion vector (AMV) wind from a geostationary satellite (GEOAMV), scatterometer oceanic surface winds (Scatwind), and precipitable water vapor from global positioning system (GPSPW). The observation errors depending on each observation platform, variable, and vertical levels are assigned based on the default observation error statistics provided in WRFDA system (Table 2). All observations are spatially thinned by 20 km except for AMV thinned by 200 km as done by Warrick (2015), Cotton et al. (2016), and Shin (2016)."

In addition, since we liked to get information from more observation data than those obtained from real-time numerical forecast analysis, we combined the E3DVAR analysis and ERA5 forecast as in Eq. (7) in the manuscript. This part is explained in the response to the next comment in more detail.

B. The authors should present more advantages of EARR compared to other regional reanalysis system. Otherwise, the value of the new regional reanalysis system is less. For example, ERA5 reanalysis has rich satellite data with 25Km resolution, EARR only assimilates conventional observations and Quick scant wind but half domain of ERRA is ocean. EARR uses ERA5 as initial value and LBC, the forecast has much information of ERA5.

Authors' response: The EARR uses much more information than the E3DVAR using WRF, since we combined two information from E3DVAR and ERA5 to produce the EARR. EARR uses ERA5 as LBC, but combines E3DVAR analysis and ERA5 6 h forecast to get initial condition. In order to take advantage of more observations and advanced data assimilation method used for ERA5, a new advanced hybrid gain (AdvHG) data assimilation method, which combines E3DVAR and ERA5 based on WRF model, is newly proposed and investigated in this study.

As we mentioned in the manuscript, this is a very efficient approach because of the cost savings as well as the use of the high-quality latest reanalysis from ECMWF assimilating all currently available observations with the state-of-the-art and advanced technology. As a result, the precipitation of EARR is shown to be more accurate than that of ERA5 for both summer and winter seasons over East Asia. In a regional sense, a higher resolution regional-based reanalysis considering regional weather and climate characteristics is more and more required, and the method presented in this study shows the possibility of integrating various data, observations, and methodologies to suit regional needs.

C. It is better to provide some experiments to support the reason why use ERA5 forecast field is better than deterministic analysis in page 7.

Authors' response: In this study, 6 h forecast of ERA5 based on WRF model is used instead of ERA5 reanalysis fields to maintain the consistency between different modeling systems as well as different resolutions. ERA5 reanalysis fields are generated based on the Integrated Forecasting System (IFS) of ECMWF with around 30 km horizontal resolution. If ERA5 reanalysis is directly used to combine with E3DVAR analysis based on WRF model whose horizontal resolution is 12 km, there could be some imbalance occurred in meteorological fields resulting from two different modeling systems. Thus, to reduce the imbalance and ensure the stability and consistency during analysis process, 6 h forecast of ERA5 is used instead of ERA5 deterministic reanalysis in Advanced Hybrid Gain method.