Assimilation of Airborne Doppler Radar Observations Using the Unified GSI-based Hybrid Ensemble-Variational Data Assimilation System for HWRF

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The GSI-based hybrid DA system showed significant improvement for global forecast compared to GSI (3DVAR) and became operational on May 22, 2012 for the Global Forecast System (GFS).

GSI is a unified system which provides data assimilation for all operational global and regional forecast system.
Efforts are being conducted to integrate the same GSI-based hybrid DA system with operational regional forecast systems.

Unifying GSI-based hybrid DA system with operational regional systems facilitates faster transition to operations.

The focus of the project is the extension, application, extensive testing and research of the GSI-based hybrid data assimilation for the HWRF modeling system at high resolutions.

Also motivated by encouraging results of ensemble based data assimilation for tropical cyclones.
Background

850 mb temperature increment after assimilating ground based radar radial velocity using WRF 3DVAR (a) and WRFVAR hybrid (b, Wang et al. 2008)
GSI-based Hybrid ensemble-VAR DA system

1-way coupling

- member 1 forecast
- member 2 forecast
- member k forecast
- control forecast

- EnKF
- EnKF analysis 1
- EnKF analysis 2
- EnKF analysis k

- Ensemble covariance

- GSI-ECV
- control analysis

data assimilation

Wang et al. 2012

First guess forecast
GSI-based Hybrid ensemble-VAR DA system
2-way coupling

First guess
forecast

Wang et al. 2012
Code changes related to Airborne radar data so far

**EnKF**

-- Add airborne radar wind observation assimilation capability

**GSI**

-- Separate the Fore and Aft scans during data thinning in GSI (TDR data transferred remain the same, changes made inside GSI code)
-- option to assimilate TDR data based on leg
Experiment Setup

- **Model**: HWRF $\Delta x=9\text{km}$
- **Observations**: radial velocity from Tail Doppler Radar (TDR)
- **Case**: IRENE 2011
- **Initial and LBC ensemble**: GFS global hybrid DA system
- **Ensemble size**: 40
DA cycling configuration

GSI (3DVar)

Hybrid (1 way coupling)

EnKF
TDR data distribution
TDR data distribution
700 mb wind increment

GSI

EnKF

hybrid
Verification against independent flight level wind speed

http://www.aoml.noaa.gov/hrd/HRD-P3_fl.html

First Leg

**GSI**

**EnKF**

**Hybrid**

![Graphs showing flight level wind speed for GSI, EnKF, and Hybrid](image-url)
Verification against SFMR wind speed

http://www.aoml.noaa.gov/hrd/format/sfmr.html

First Leg

![Graphs showing SFMR wind speed for GSI, EnKF, and Hybrid models](graphs.png)
Verification against independent flight level wind speed

Last Leg

GSI

EnKF

Hybrid
Verification against SFMR wind speed

Last Leg

GSI

EnKF

Hybrid

SFMR wind speed

km

SFMR wind speed

km

SFMR wind speed

km
Vr RMSE vs. Spread during DA

RMS fit to Vr

Vr ensemble spread

RMSD (m/s)

Spread (m/s)

Time

Time
MSLP during DA

![Graph showing MSLP (hPa) over time for different methods: GSI, EnKF, Hybrid, and Best track.]
Comparison with radar wind analysis

Comparison with radar wind analysis

HRD radar wind analysis @ 1km

GSI @ 1000mb

Hybrid/EnKF @ 1000mb
Comparison with radar wind analysis

HRD radar wind analysis @ 3km

GSI @ 700mb

Hybrid/EnKF @ 700mb

m/s
Track forecast

EMC: HWRF official forecast
NoDA: no TDR assimilation
GSI: assimilating TDR using GSI
EnKF: assimilating TDR using EnKF
Hybrid: assimilating TDR using hybrid
Intensity forecast

EMC: HWRF official forecast
NoDA: no TDR assimilation
GSI: assimilating TDR using GSI
EnKF: assimilating TDR using EnKF
Hybrid: assimilating TDR using hybrid
Summary and ongoing work

a. The GSI-based hybrid EnKF-Var data assimilation system was expanded to assimilate TDR data for HWRF.
b. TDR data showed positive impact on TC track and intensity forecasts and verification against independent observations.
c. Various diagnostics and verifications suggested ensemble-based data assimilation (hybrid, EnKF) provided more skillful TC analysis and forecasts than the GSI.
d. Testing more missions/cases.
e. Testing dual resolution 3km/9km hybrid; 3km’s own hybrid.
f. Developing and testing GSI/EnKF hybrid with moving nests.
g. Add and test more observations.
h. Develop and research on various new capabilities for hybrid.