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Introduction

NOAA's next generation Rapid Refresh Forecast System (RRFS), a unified hourly-updated, convective-scale ensemble data assimilation and forecasting system, is currently under development and testing. This systems are based on the concept of unifying around the Finite Volume Cubed-Sphere (FV3) dynamical core. The FV3 has been operational for global NWP and will be for convective-scale applications as well. This limited area configuration is poised to underpin the rapidly updated, convection allowing ensemble system in the NCEP production suite in 2023 approximately. The current phase of testing and development for RRFS has been expanded to the large domain with grid size, 65 vertical levels, and 2-hPa model. The RRFS DA test features a 6-hour long assimilation cycle, with hourly forecast/analysis components, ending with a 60 hours free forecast. The RRFS test system run twice a day at 00Z and 12Z with hourly data assimilation with ICs and Boundary from operational 13-km GFSFV3.

The data assimilation of RRFS is conducted using a hybrid 3DVar method within GSI assimilating both conventional and satellite radiance data from the following instruments onboard polar orbiting satellites: AMSUA, MHS, IASI, ATMS and CrIS, and ABI from geostationary satellite GOES-16. Observations that feature continuous, low latency coverage over a high-resolution limited area domain are of particular importance in the emerging RRFS framework. Recently, we updated the polar orbiting satellite radiance data source to DBNet (Direct Broadcast Network) in the real-time experiment FV3LAM DA, and attempting to assimilate cloudy microwave radiance from both AMSUA and ATMS.

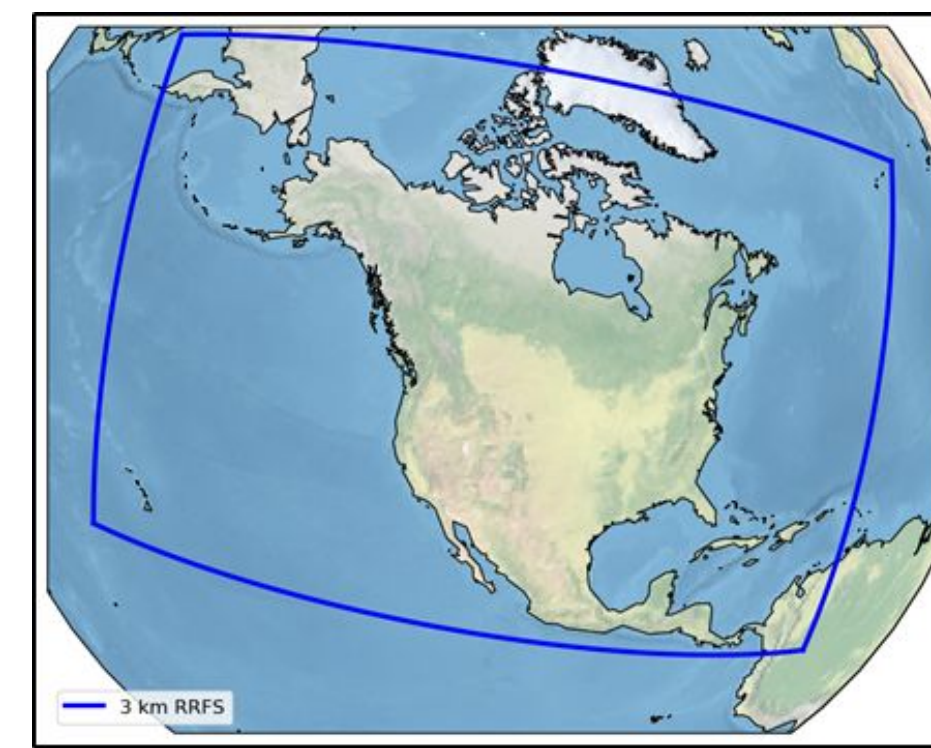


Fig1. RRFS domain configuration

DBNet Radiance data in FV3 Regional System

Recent DBNet Radiance Update in RRFS

- Satellite radiance data from both EARS and DBNet have been used in RRFS real-time test experiment. Use of these data are important for rapidly updated data assimilation systems as these transmission services reduce observational latency by a considerable amount thus leading to significant increases in observation availability for the RRFS data assimilation system
- The updated satellite instruments include ATMS, MHS, and IASI from EAR, and ATMS, CRIS, and IASI from DBNet. AMSUA from EARS has been used in the developmental real-time parallel since 2019.
- The assimilation of the EARS and DBNet radiance data largely increased the data amount for the hourly analysis, especially for ATMS and CrIS data (Fig. 2), added the data coverage to some zero data area and hours (Fig.3 &4).
- MHS and IASI data counts also increased, but not to the degree of ATMS and CrIS, figures are neglected here.

Fig3. Brightness Temperature O-F from ATMS ch. 8

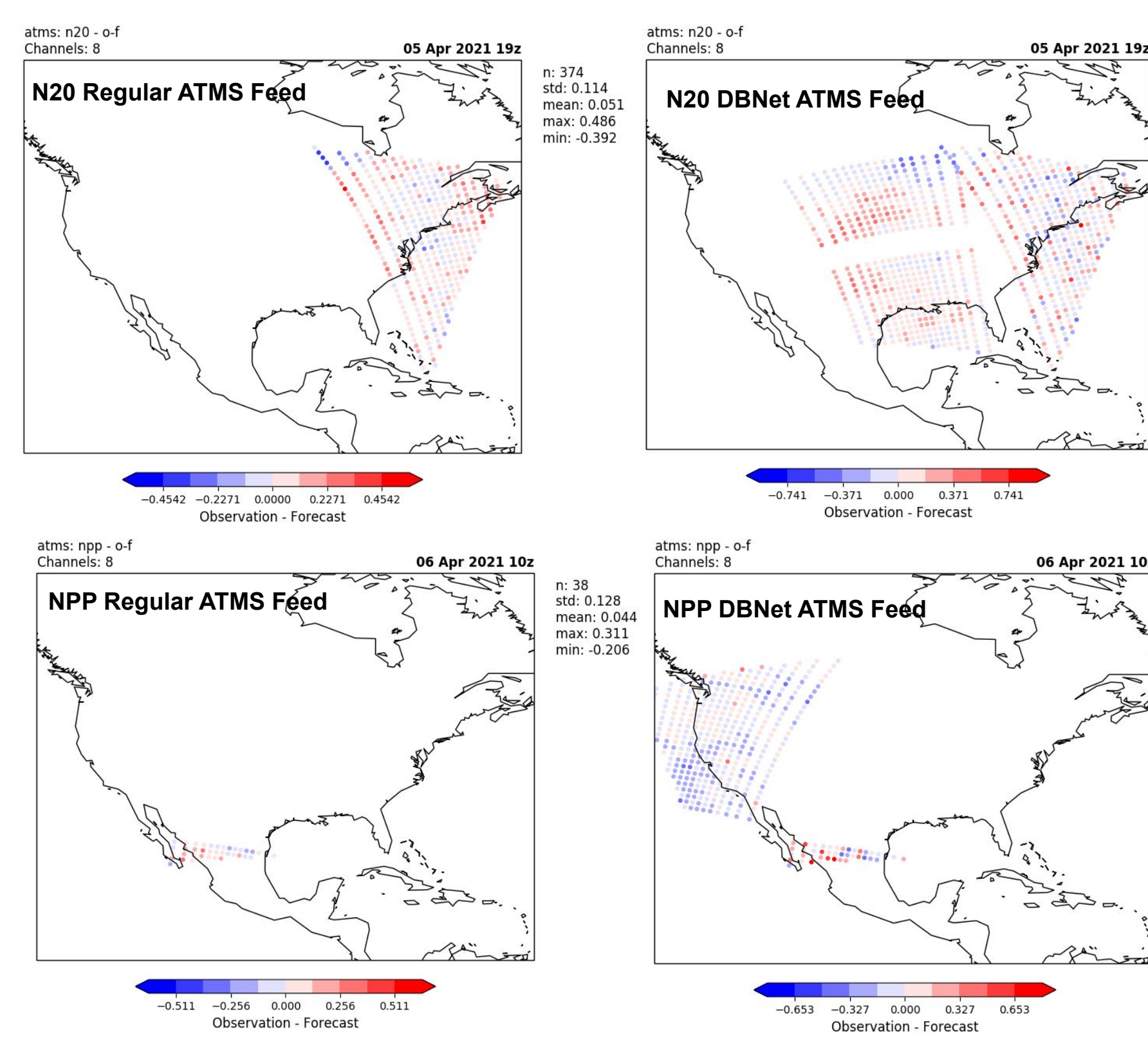


Fig 4. Brightness Temperature O-F from CRIS ch. 1058

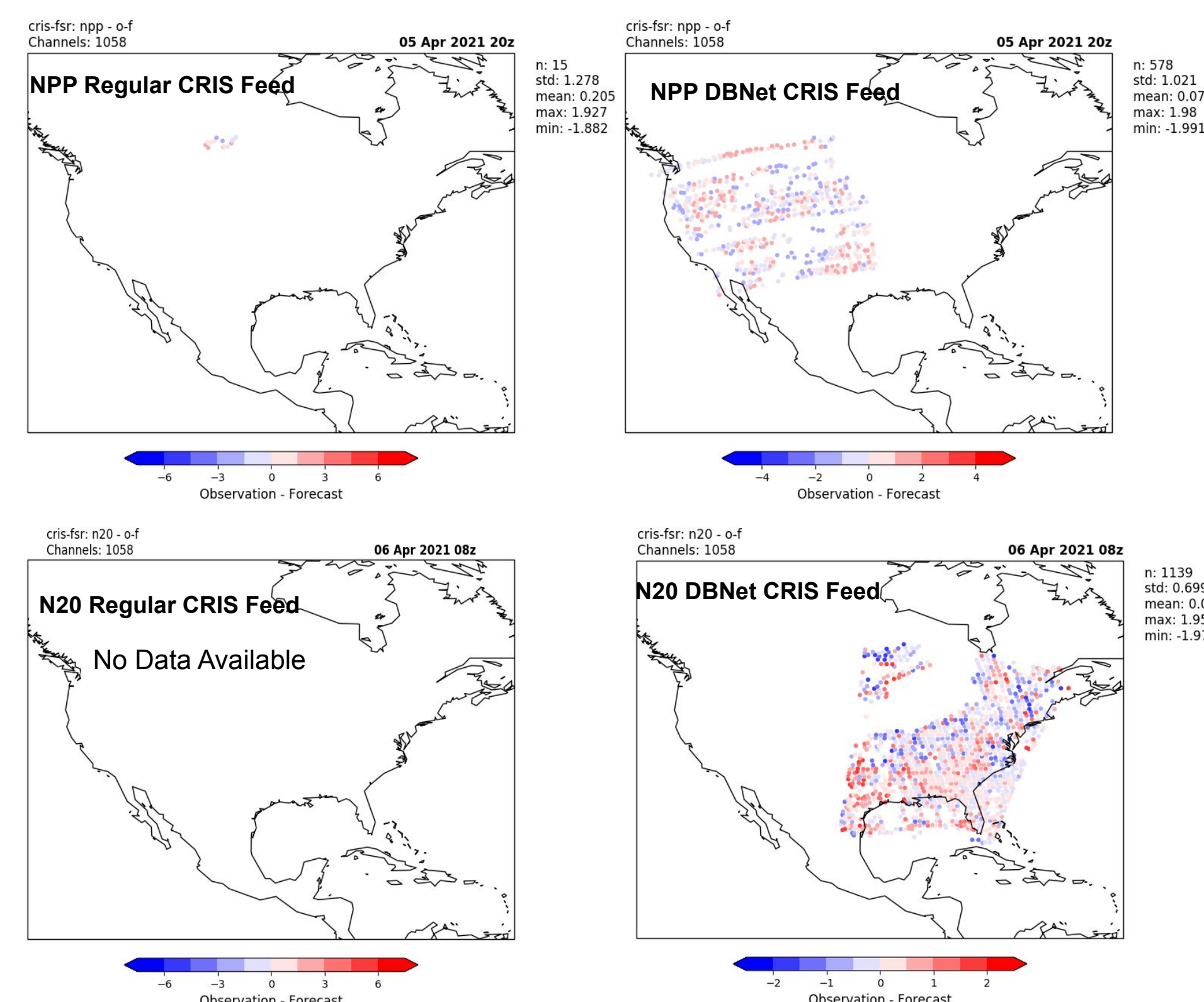
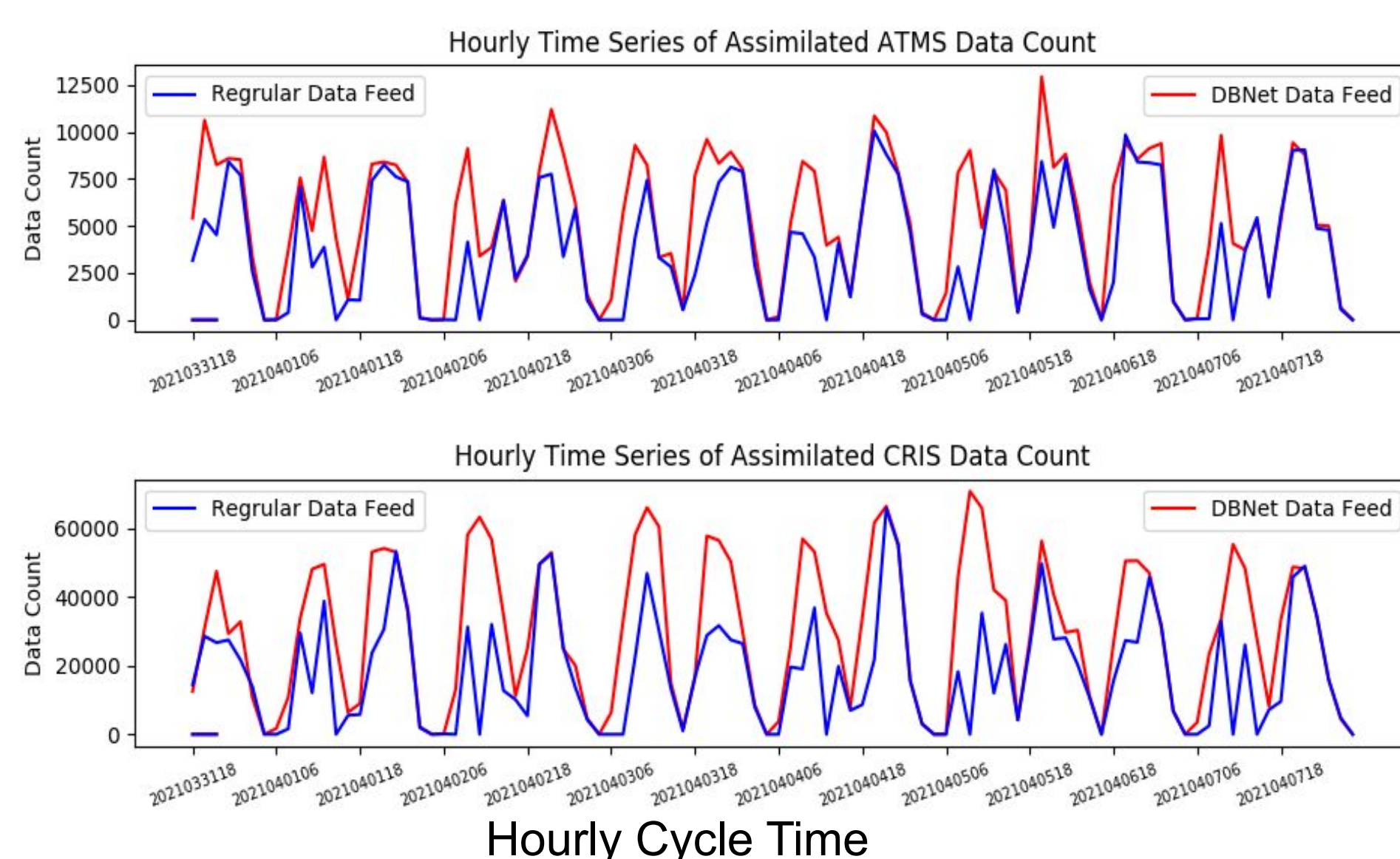


Fig.2: Time Series of Data Used in RRFS



Assimilation of Microwave Cloudy Radiance

MW cloudy radiance assimilation status in NCEP

- Global FV3 (FV3GFS) assimilate clear and cloud-affected AMSU-A and ATMS radiances directly in operational; the capability of assimilating precipitation-affected radiances had been developed for testing in FV3GFS
- Regional FV3 (FV3LAM) test system assimilate only clear-sky AMSUA and ATMS radiance, without considering the effect of cloud or precipitation.
- This work examines whether the FV3GFS capability of assimilating precipitation-affected radiance from AMUSA and ATMS could be extended to RRFS DA.

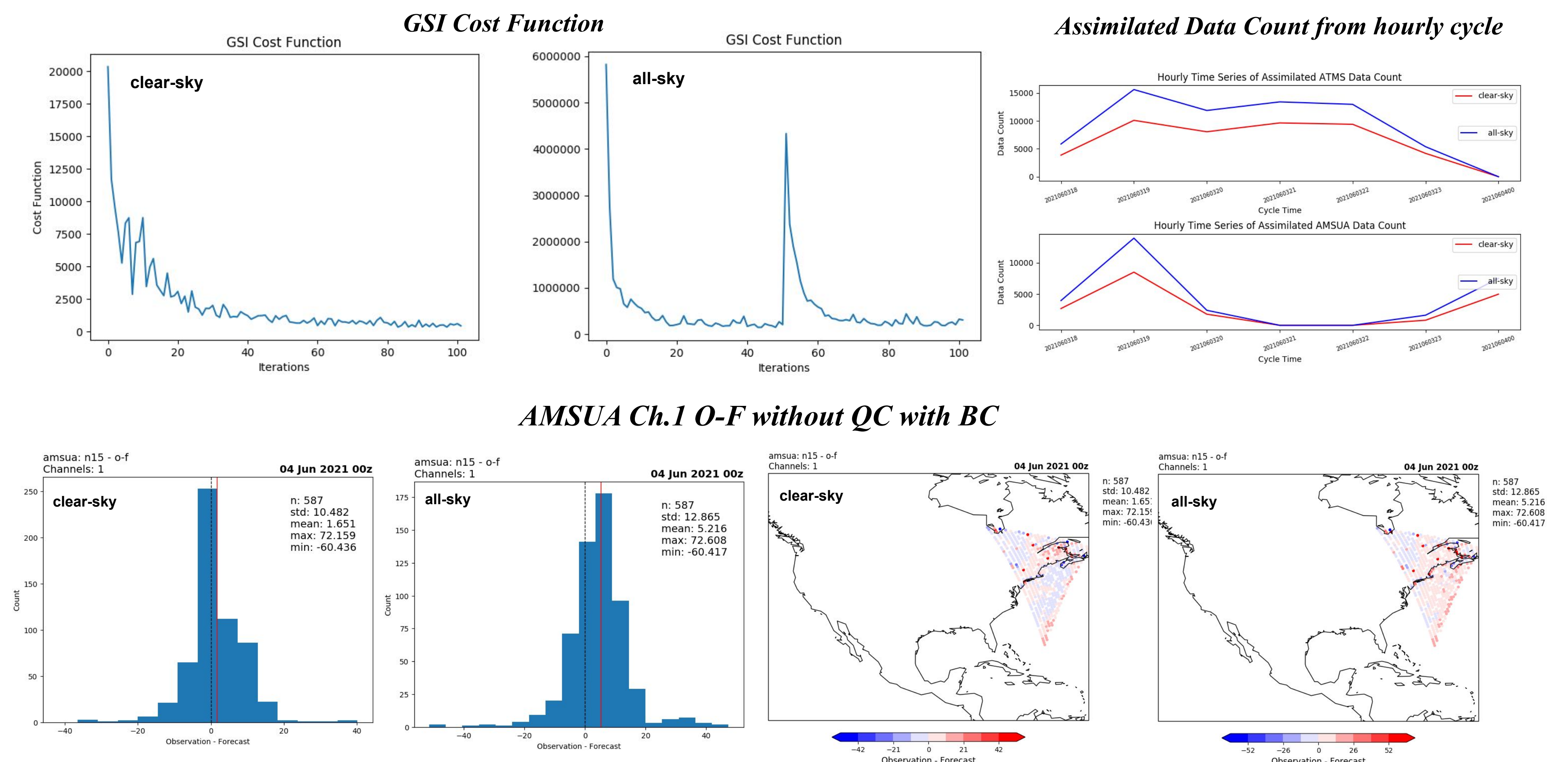
Description for assimilating all-sky MW in RRFS

- Modify regional FV3 interface within GSI to read in and write out the precipitating hydrometeors (ql, qi, qr, qs, qg), which were chosen to be the new control variables
- Use the same GSI code for global to assimilate the precipitating-affected AMSU-A and ATMS radiances over ocean only
- Radiance transfer model is CRTM version 2.3.0
- Test domain is mainly cover CONUS which is the current real-time test domain called FV3LAM

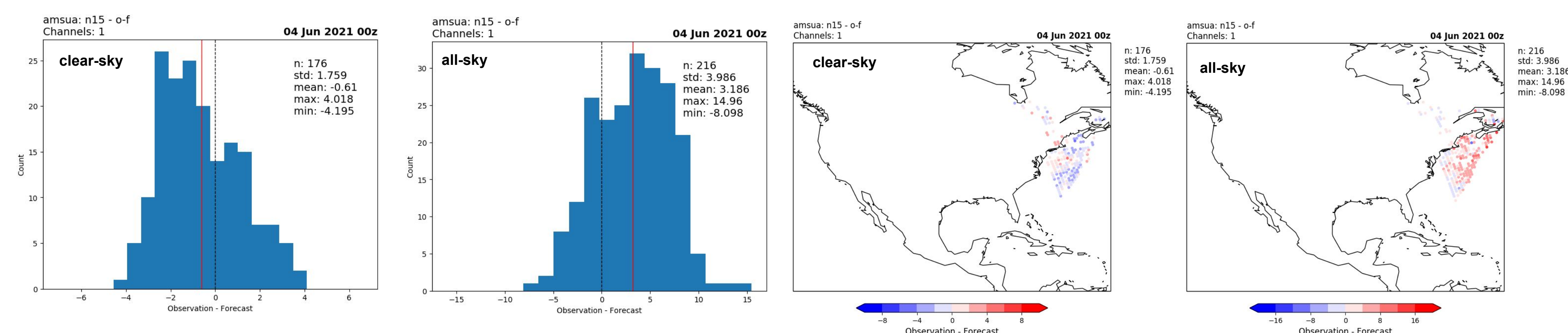
FV3LAM Selected MW Instrument and Channels

Instrument	Selected Channels in FV3LAMDA
AMSUA_NOAA-15	1, 2, 3, 4, 5, 7, 8, 9, 10, 12, 13, 15
AMSUA_NOAA-18	1, 2, 3, 4, 6, 10, 12, 13, 15
AMSUA_NOAA-19	1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 15
AMSUA_Metop-A	1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 15
AMSUA_Metop-B	8, 9, 10, 11, 12, 13
AMSUA_Aqua	8, 9, 11, 12, 13
ATMS_NPP	1,2,3,4,5,6,7,8,10,11,12,13,14,16,17,18,19,20,21,22
ATMS_NOAA-20	1,2,3,4,5,6,7,8,10,11,12,13,14,16,17,18,19,20,21,22

Preliminary result of assimilating precipitation-affected AMSUA radiance



AMSUA Ch.1 O-F with QC with BC



- The test for assimilating precipitation-affected cloudy microwave radiance into high resolution 3-km limited area FV3 DA system has examined the basic code that fully tested in GFSFV3 also works limited DA
- Both quality control and bias correction were adopted directly from GFSFV3 DA, which may need more specific treatment for limited area DA. Especially for hourly DA cycle.
- There is not many data increased from precipitation-affected pixels for FV3LAM which cover the north America continental. But it will benefit NOAA's future RRFS system which will be expanded to Pacific ocean and Atlantic ocean