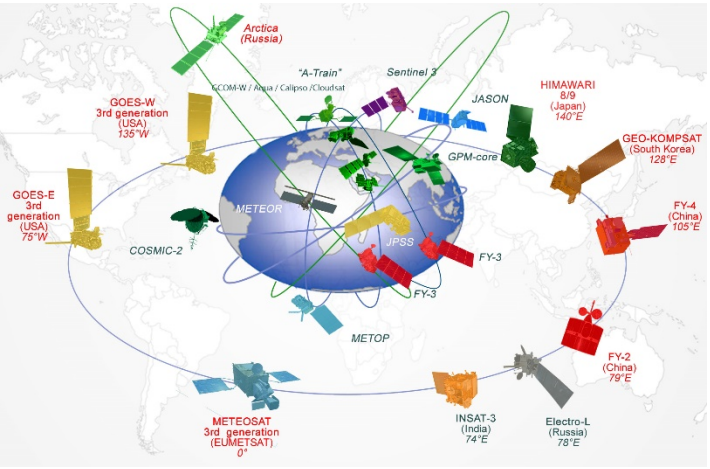


CMA NWP Impact Assessment of Satellite data

Presented to CGMS-49 plenary session, agenda item [05]

Main Instruments

Optical Imager

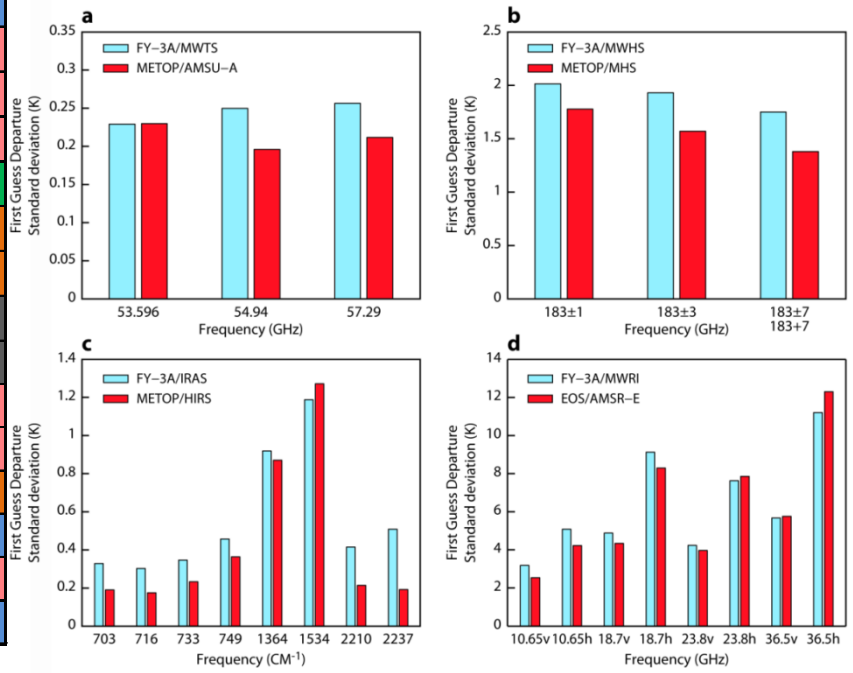
Atmospheric Sounder

Microwave Imager

Atmospheric Composition

Radiation Budget

Satellite		No. of Instruments	Name in Abbrev.
FY-1	FY-1 A/B	2	5-channel VIRR
	FY-1 C/D	2	10-channel VIRR
FY-2	FY-2 A/B	1	3-channel VISSR
	FY-2 C/D/E	1	5-channel VISSR
FY-3	FY-3 A/B	10	10-channel VIRR
			MERSI
			IRAS
			MWTS
			MWHS
			MWRI
			SBUS
			TOU
			ERM
			SIM
	FY-3C	11	GNOSS
	FY-3D	10	HIRAS
			GAS
FY-4	FY-4A	3	AGRI
			GIIRS
			LMI



ECMWF, 2011: The data quality is now comparable to that from equivalent US and European meteorological satellites

Impact assessment

- **CMA**
  - ✓ **NWP**
  - ✓ **Global Reanalysis**
- **International NWP Communities**
  - ✓ **ECMWF**
  - ✓ **UK MetOffice**
  - ✓ **Others**

CMA NWP Center

Courtesy of Juan Li

GRAPES

(Global/Regional Assimilation and Prediction System)

GRAPES_GFS

Grid size: 25 km

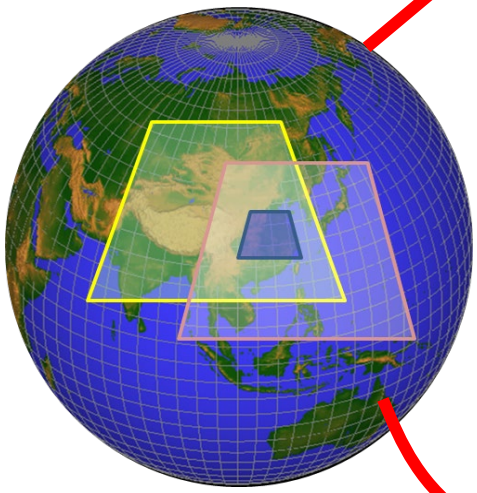
Layers: 87(～0.1hPa)

Forecast range:

cyclic system

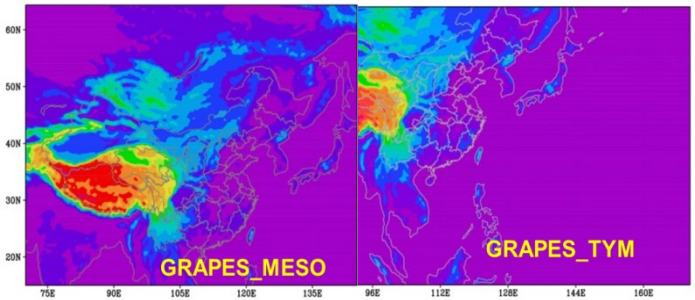
240 h fcst. at 00 and 12 UTC

DA: 4DVar



GRAPES_Meso

System	GRAPES_MESO	GRAPES_TYM
Domain	70º~145ºE，15º~64ºN	90º~171ºE，0º~51ºN
Model Top	50hPa	50hPa
Resolution	0.10º/L50	0.10º/L50
Initial Time	3-hourly cycle	00UTC、12UTC
Analysis	3DVAR + cloud analysis	GFS
Vortex initialization	NO	Relocation+ BOGUS
Forecast length	00 & 12UTC 84h	120h
Physics	RRTM LW Dudhia SW WSM 6 KF-eta Monin-Obukhov NOAH MRF PBL	RRTM LW Dudhia SW WSM 6 SAS Monin-Obukhov SLAB YSU



GRAPES_Meso-3km

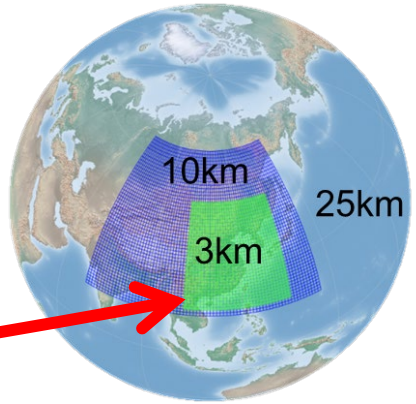
Grid size: 3 km

Layers: 50(～50hPa)

Forecast range:

36h at 00, 12UTC

Analysis	GRAPES_GFS + cloud analysis
Physics	RRTM LW Dudhia SW WSM 6 Monin-Obukhov NOAH MRF PBL



Satellite observations assimilated in GRAPES

Foreign satellites

Instruments	Observations
AMSU-A (NOAA-15/18/19, Metop-A/B)	Microwave (T), Radiance
MHS (NOAA-18,19, Metop-A/B),	Microwave (H), radiance
ATMS(NPP)	Microwave (T, H), radiance
AIRS (Aqua),	Infrared (T), radiance
IASI (Metop-A/B)	Infrared (T), radiance
RO (COSMIC-1/2, Metop-A/B/C，PAZ,KOMPSAT-5，TerraSAR-X, TanDEM-X)	Refractivity
ASCAT(Metop-A/B)	Wind
AMV(METEOSAT-9,MODIS, etc)	Wind

Fengyun satellites

Instruments	Observations
MWTS-2 (FY-3D)	Microwave (T), radiance
MWHS-2 (FY-3C/D)	Microwave (H), radiance
HIRAS (FY-3D)	Infrared (T), radiance
MWRI(FY-3D)	Microwave (H), radiance
GNOS (FY-3C/D)	refractivity
GIIRS(FY-4A)	Infrared (T), radiance
AGRI (FY-4A)	Infrared (H), radiance
VISSR(FY-2H)	Infrared (H), radiance
AMV(FY-2)	wind

Polar-Orbiting

MWTS-2 (MicroWave Temperature Sounder-2)
MWHS-2 (MicroWave Humidity Sounder-2)
HIRAS (Hyperspectral Infrared Atmospheric Sounder)
MWRI (Micro-Wave Radiation Imager)
GNOS (GNSS Radio Occultation Sounder)

Geostationary

GIIRS (Geostationary Interferometric Infrared *Sounder*)
AGRI (Advanced Geostationary Radiation Imager)
VISSR (Stretched Visible and Infrared Spin Scan Radiometer)

Impact experiment of Fengyun satellite observations

Assimilation Experiments Settings:

System: GRAPES_GFS 4Dvar

Time period: 2019050103UTC – 2019063021UTC

Experiments: CTL experiment, TEST experiment

Experiments	Data assimilated
CTL	conventional observation (sound, synop, ships, air, satob), AMSU-A(NOAA-15/18/19, Metop-A/B), ATMS,AIRS, IASI(Metop-A/B), **MWHS-2(FY-3C/D), GIIRS(FY-4A)** and GPS RO, ASCAT
TEST	**CTRL+FY-3D HIRAS, MWTS-2, MWRI, FY-2H VISSR，FY-4A AGRI，FY-3D GNOS**

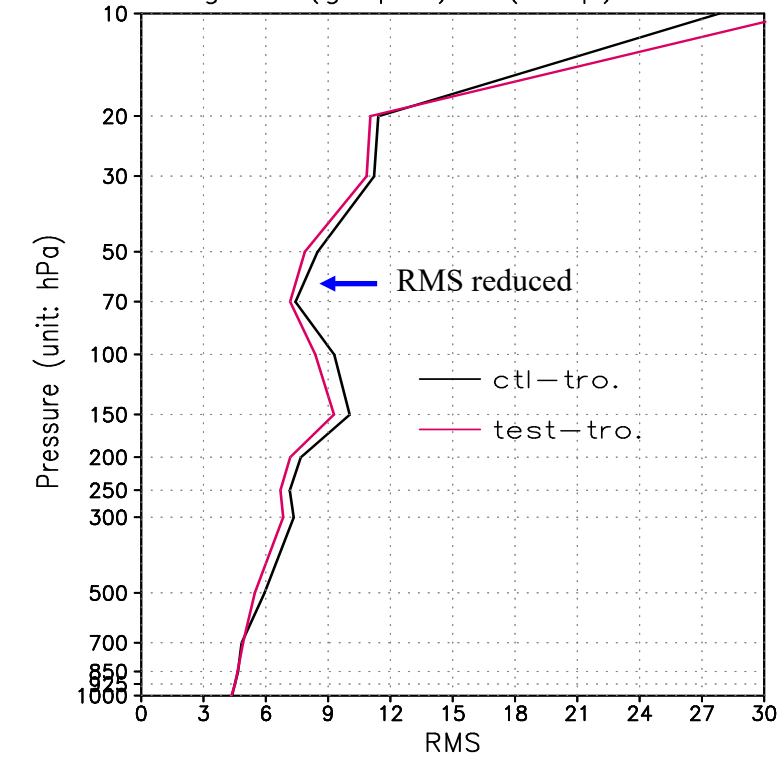
HIRAS (Hyperspectral Infrared Atmospheric Sounder)
MWTS-2 (MicroWave Temperature Sounder-2)
MWHS-2 (MicroWave Humidity Sounder-2)
GNOS (GNSS Radio Occultation Sounder)
MWRI (Micro-Wave Radiation Imager)
VISSR (Stretched Visible and Infrared Spin Scan Radiometer)
AGRI (Advanced Geostationary Radiation Imager)

Impact on analysis field

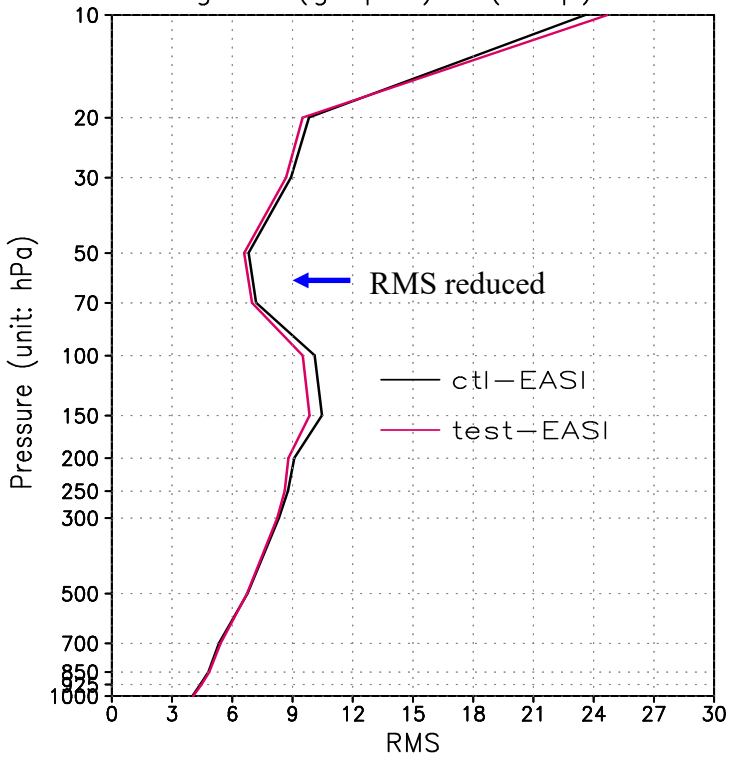
positive impact

20190501-0630 H RMS

Tropics



East Asia



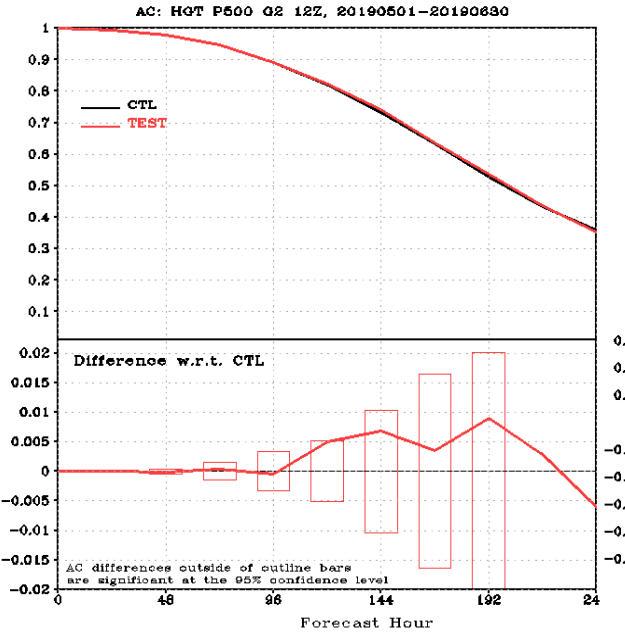
RMS of geopotential height from the analysis field difference between CTL and NCEP (black), TEST and NCEP (red)

Impact on forecasts

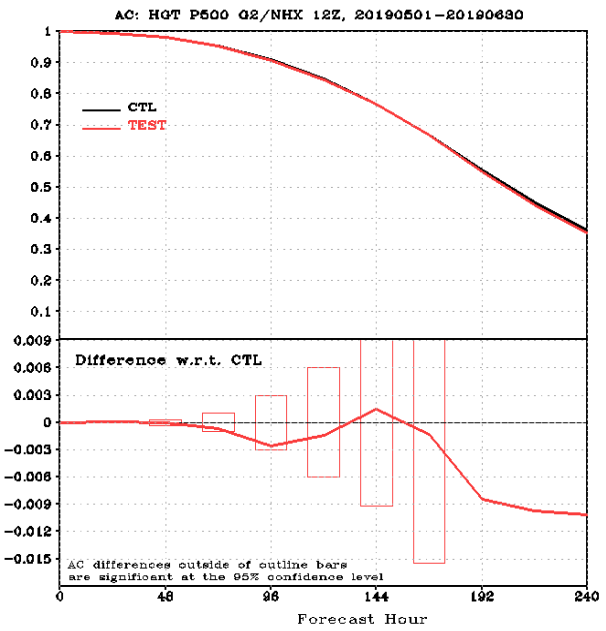
Neutral to positive impact

20190501-0630 500hPa H ACC

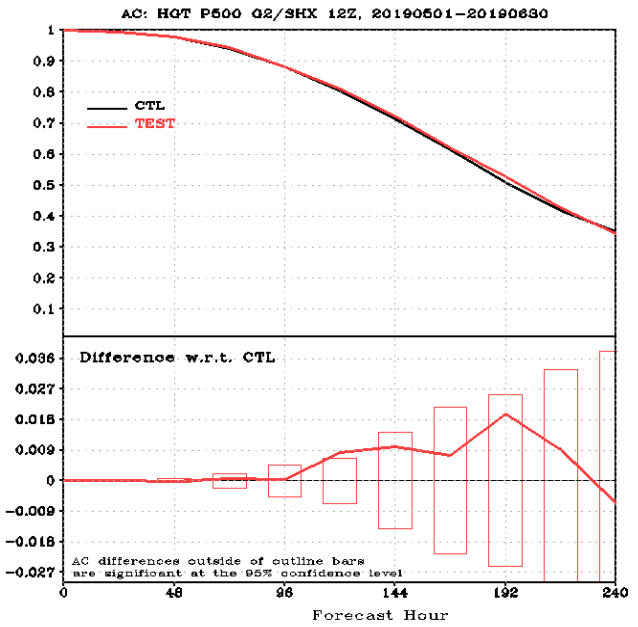
Global



Northern Hemisphere



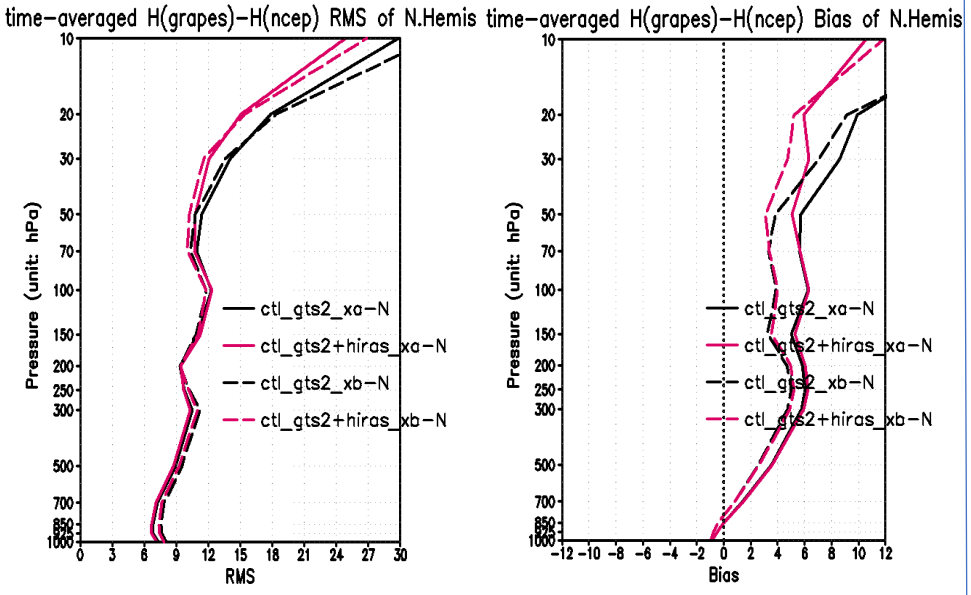
Southern Hemisphere



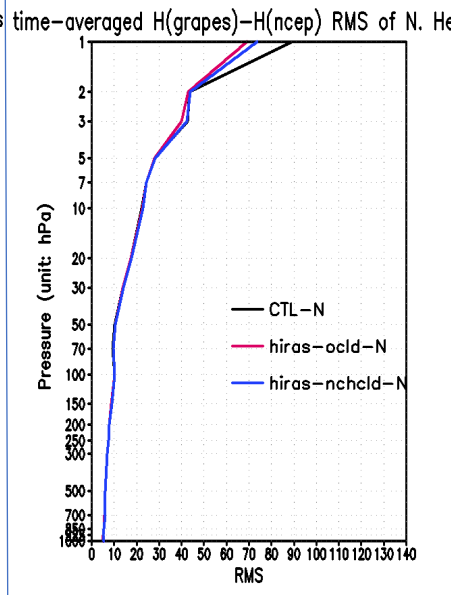
Mean ACC of 500 hPa geopotential height of CTL (black) and TEST (red)

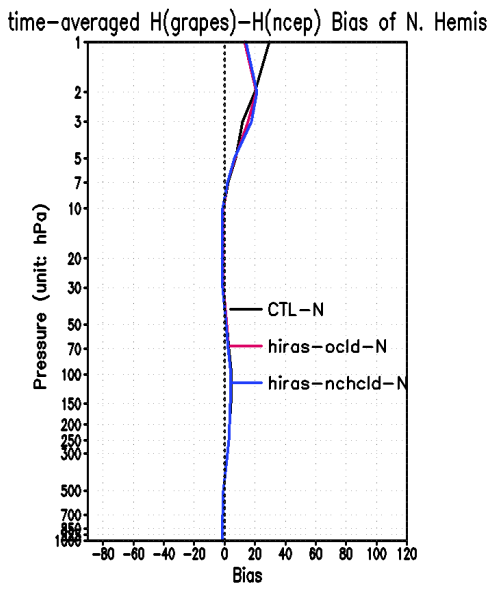
Impact of FY-3D HIRAS (June 2019)

Conventional observations + FY-3D HIRAS



All observations + FY-3D HIRAS





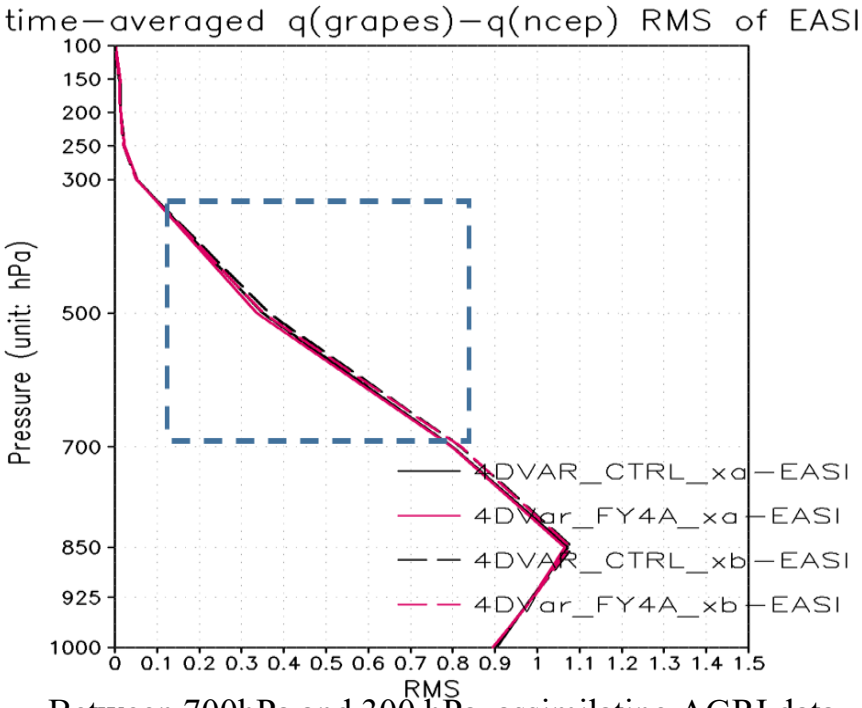
RMS of geopotential height from the analysis field difference between CTL and NCEP (black), TEST and NCEP (red)

Positive impact

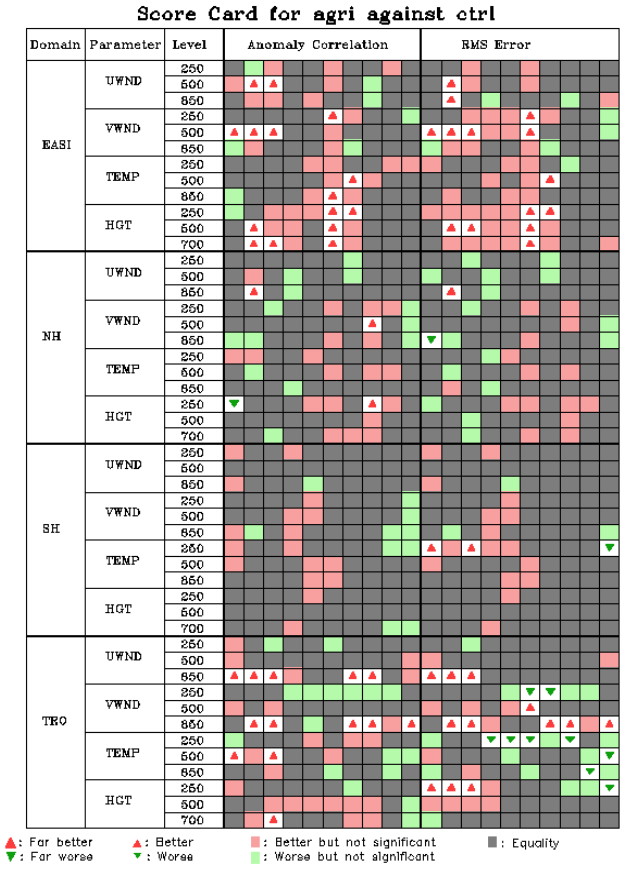
Neutral to positive impact

Assimilation effect of AGRI data

Root mean square of East Asia **vapour field** of background and analysis

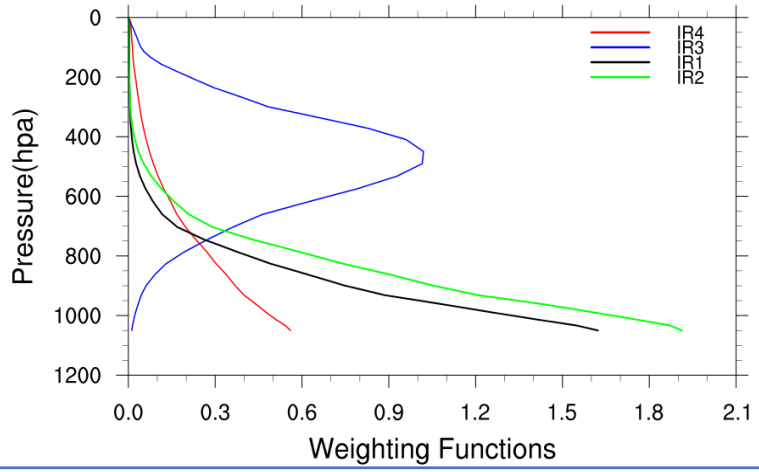


Between 700hPa and 300 hPa, assimilating AGRI data has some positive effect on the humidity field

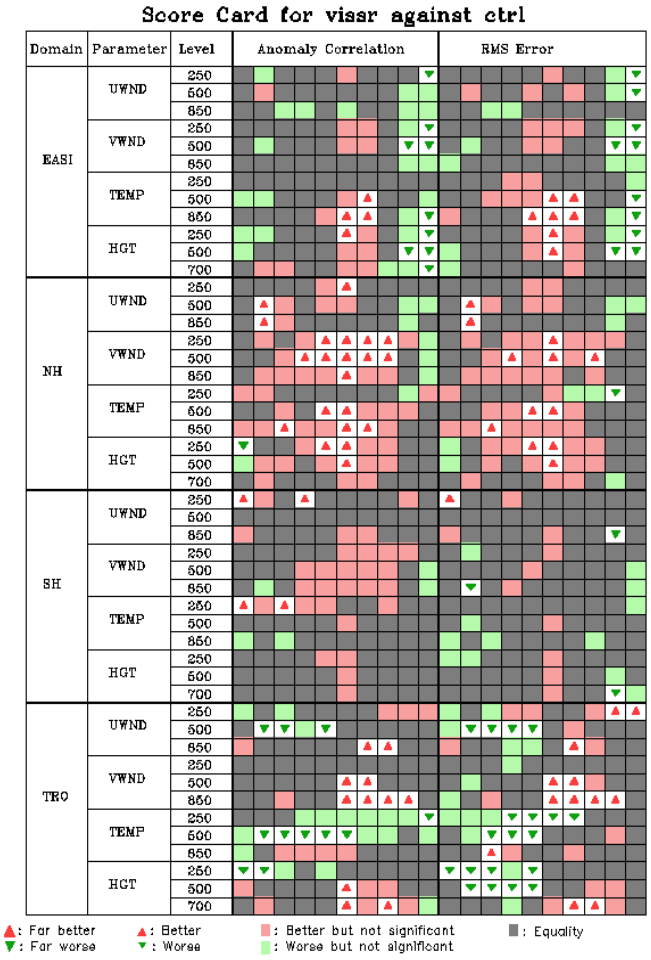


Compared with the control test. The forecast results are generally n eutral and positive. For East Asia and the Tropic, is generally positive, while the northern hemisphere and the southern are neutral.

FY2H VISSR data Quality Control and Assimilation effect



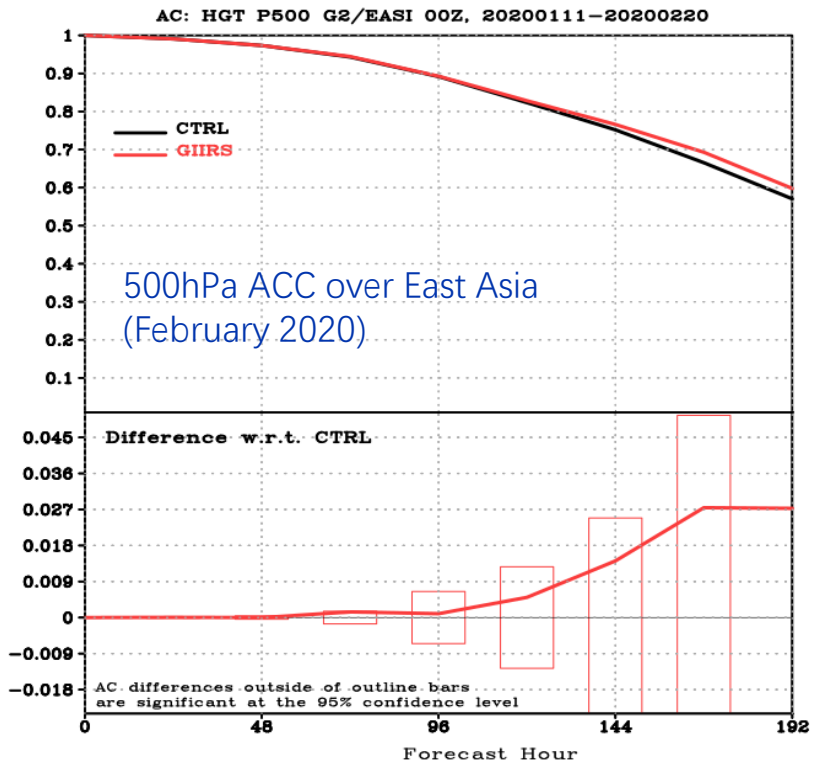
Quality Control Scheme	Specific content of the scheme
1. Abnormal brightness temperature test	Eliminate pixels with brightness temperature less than 50K and higher than 550K
2. Surface type inspection	Eliminate mixed pixels
3. Zenith Angle Quality Control	Eliminate pixels with a zenith angle greater than 60°
4. Observation error test	Eliminate pixels with O-B greater than 3 times the observation error
5. Cloud detection	（1）Match L2 cloud detection products （2）10.8μm window zone channel threshold control
6. Observation residual test	Eliminate pixels with observation residuals greater than 1.5K

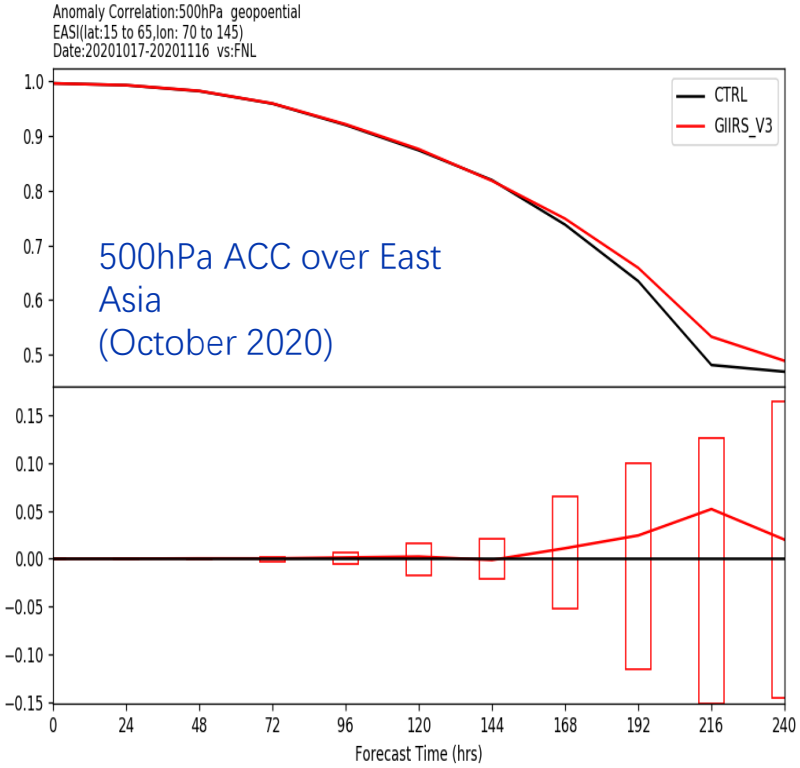


Impact of FY-4A GIIRS on Forecast over East Asia

GRAPES gloal 4D-Var
CTRL ： OPER
GIIRS： OPER + GIIRS Temp. Sounding Radiaces

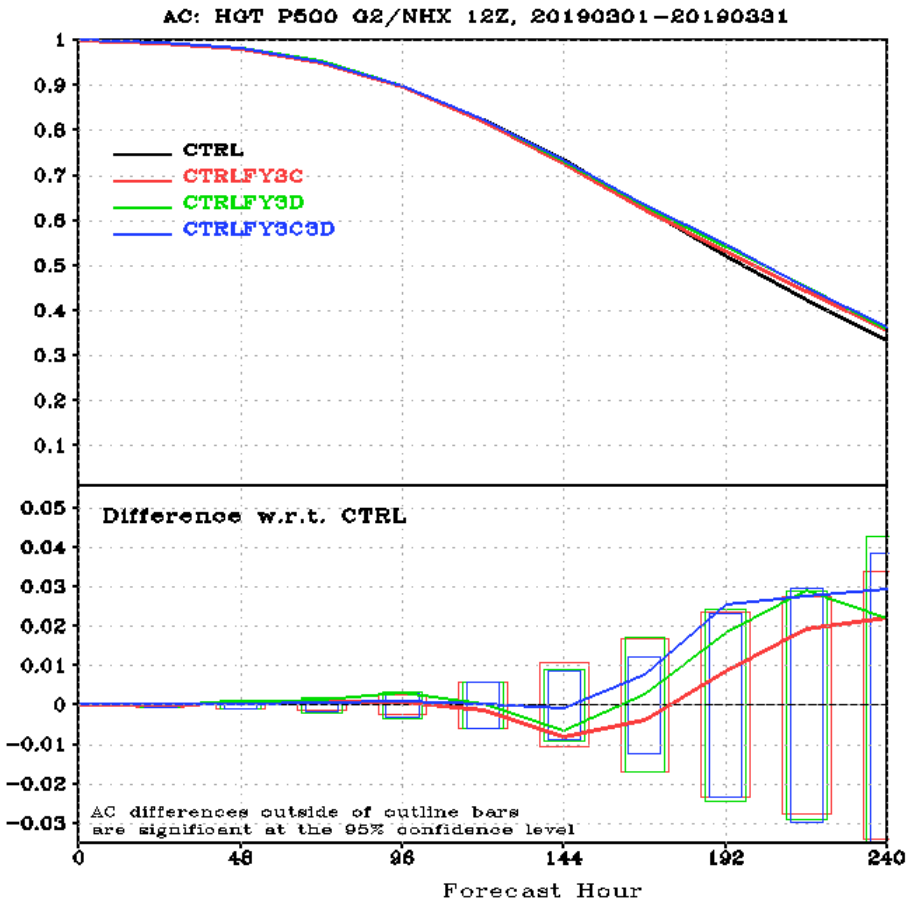
➡ **Neutral to positive impact**





Assimilation of GNOS Data in GRAPES

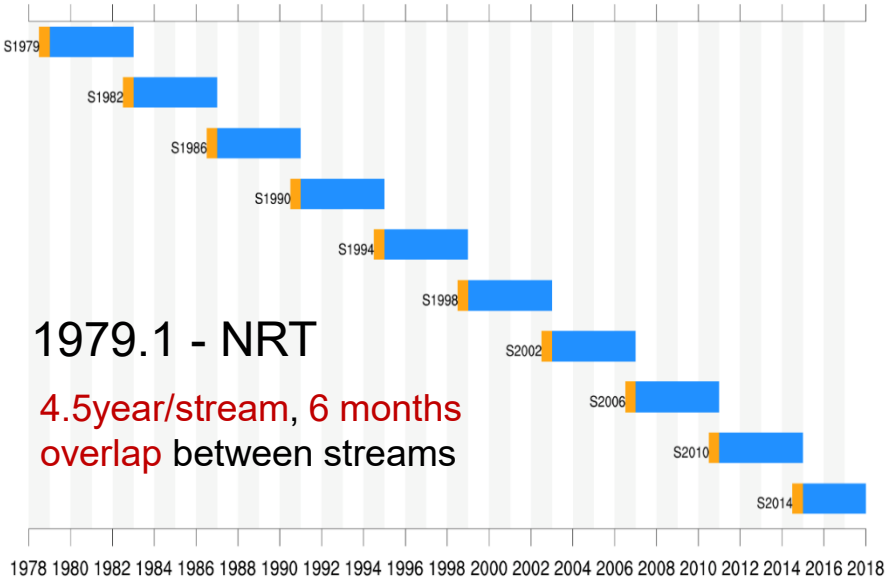
- *Anomaly correlation as a function of forecast day for four different experiments:*
  - **CTRL** (assimilation of all operational obs. except for GNOS)
  - **CTRLFY3C** (CTRL+FY3C)
  - **CTRLFY3D** (CTRL+FY3D)
  - **CTRLFY3C3D** (CTRL+FY3C+FY3D)
- *Assimilation of GNOS data in GRAPES produces a positive impact on global medium range forecast .*



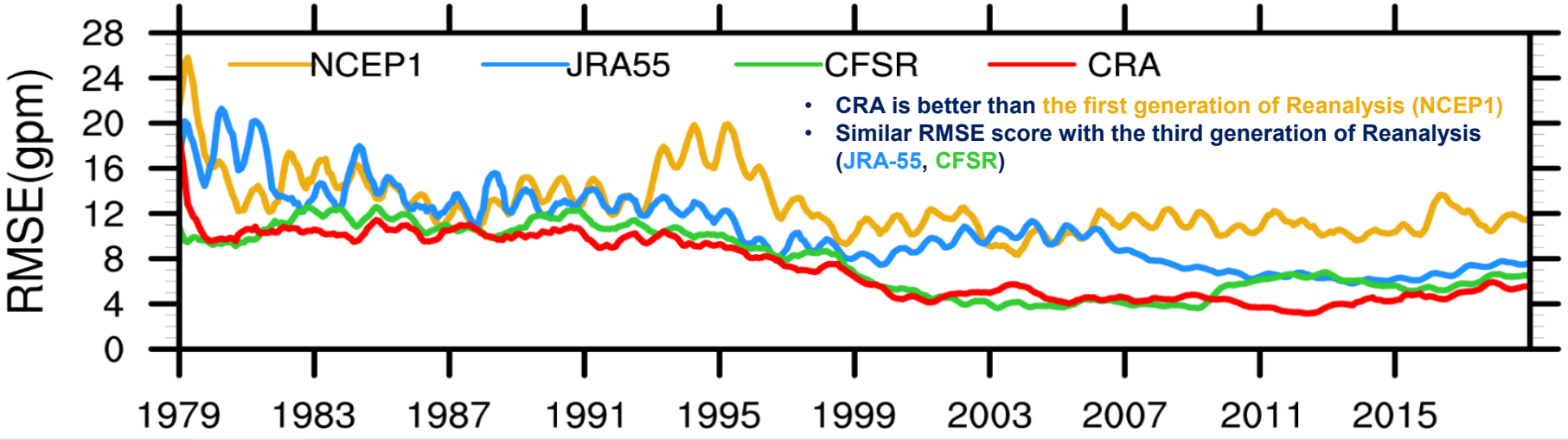
CMA Global Reanalysis

Courtesy of Lipeng Jiang

- Started in early 2014, led by the National Meteorological Information Center (NMIC) of CMA
- Include Atmosphere and Land component
- Forecast Model: GFS
  - T574 (~ 34km),
  - 64L, top at 0.27hPa (~55km)
- Data Assimilation: GSI3Dvar-FGAT
  - 6-h time window
  - VarBC for aircraft T and satellite radiances
- Finished the production in 2019

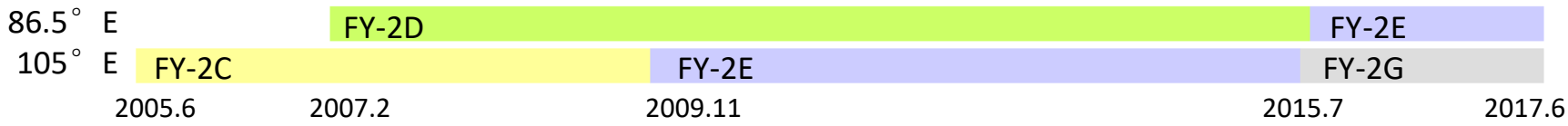


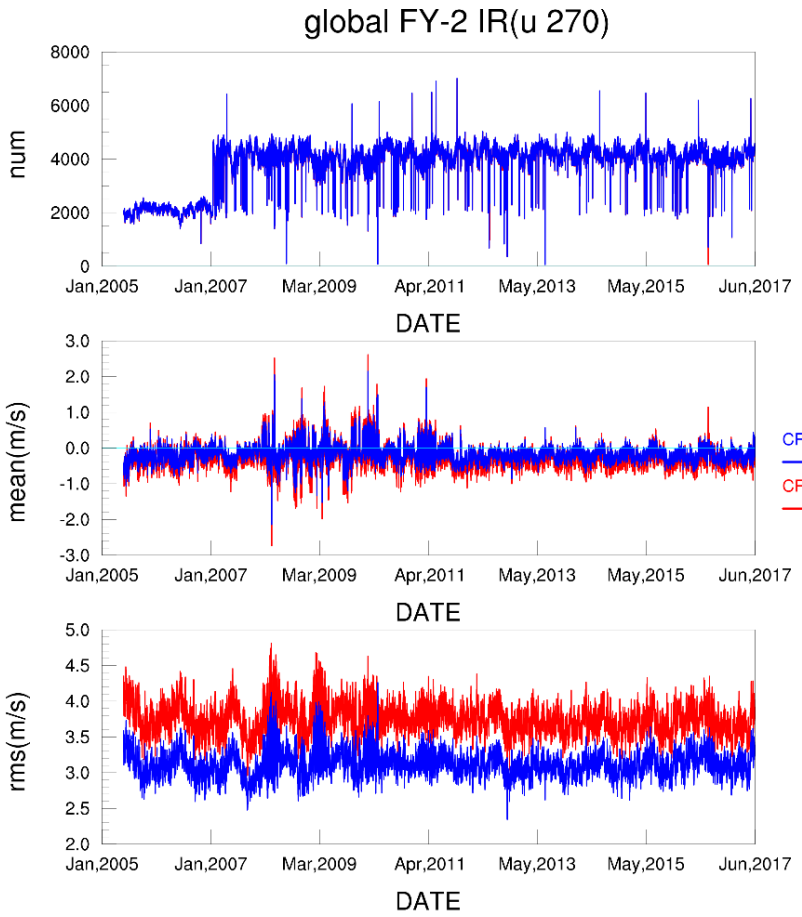
500hPa Geopotential height Error w.r.t. ERA5

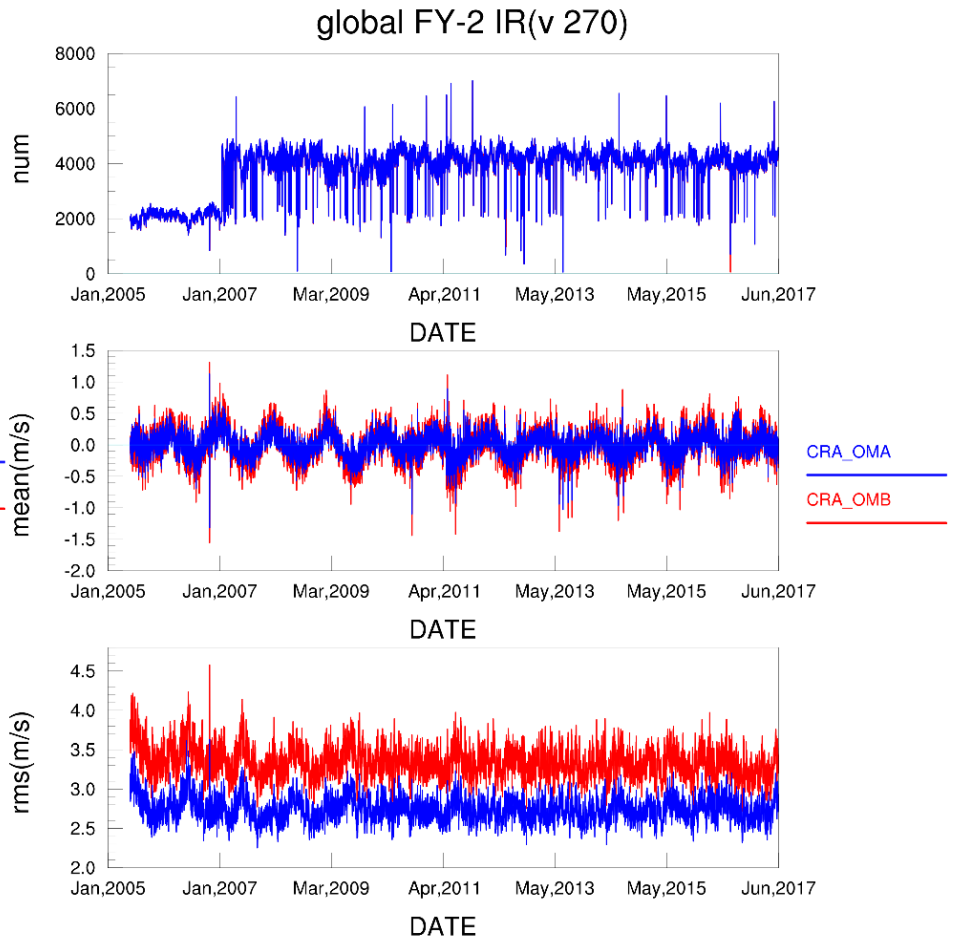


13 years of Reprocessed FY-2 AMV by NMSC were assimilated in CRA

- Reprocessed FY-2C/D/E/G IR AMV (20005.6-2017.6) AMV were used in CRA
- The mean and rms of "O-B" and "O-A" are stable.

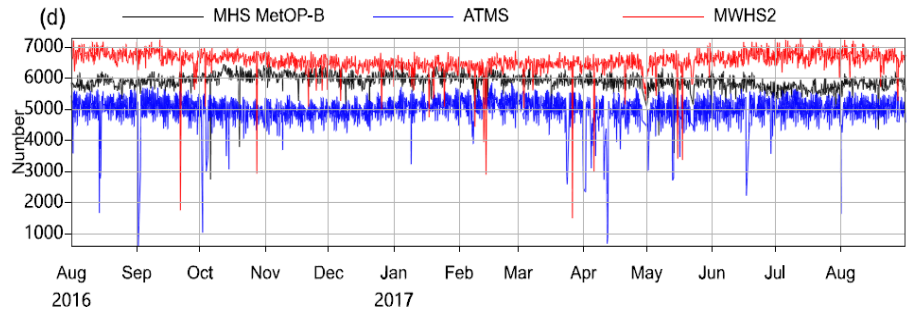


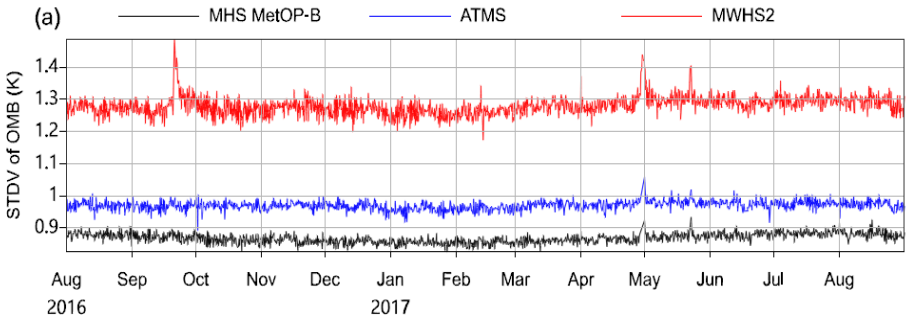


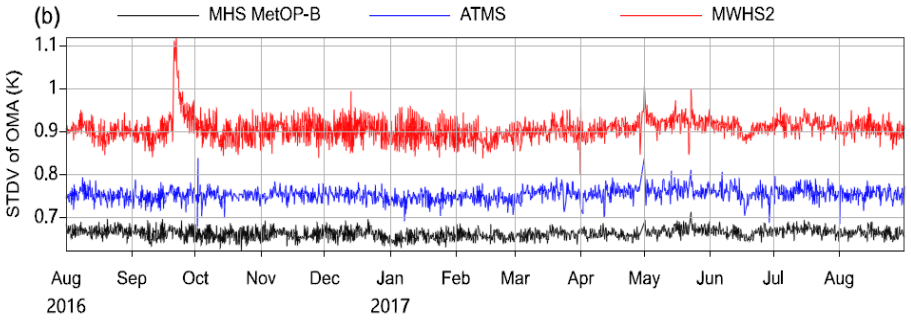


FY-3C MWHS-2 were assimilated in CRA since July, 2016

- **The number of observations passed QC is stable**
- **Comparable STDV with ATMS and MHS w.r.t. CRA 6h forecast**

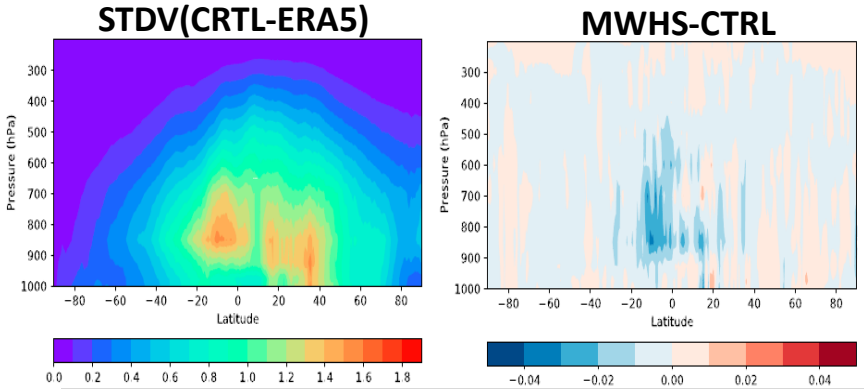




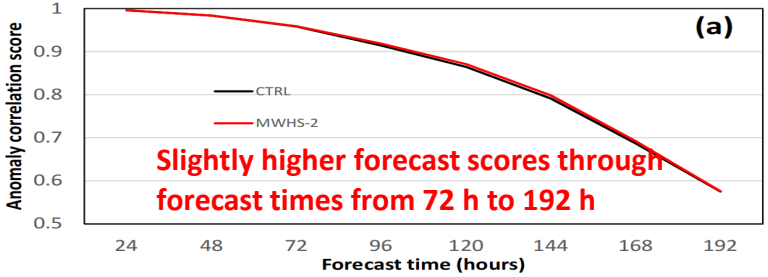


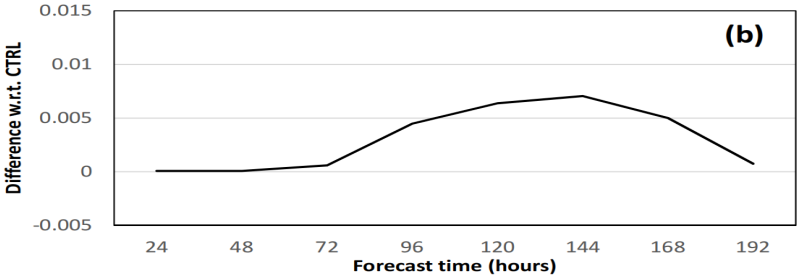
Impacts of MWHS-2 on 6h Forecasts

Improve 6h forecast scores compared with ERA5.
Error reduction can be up to 0.04g/kg in tropical region.



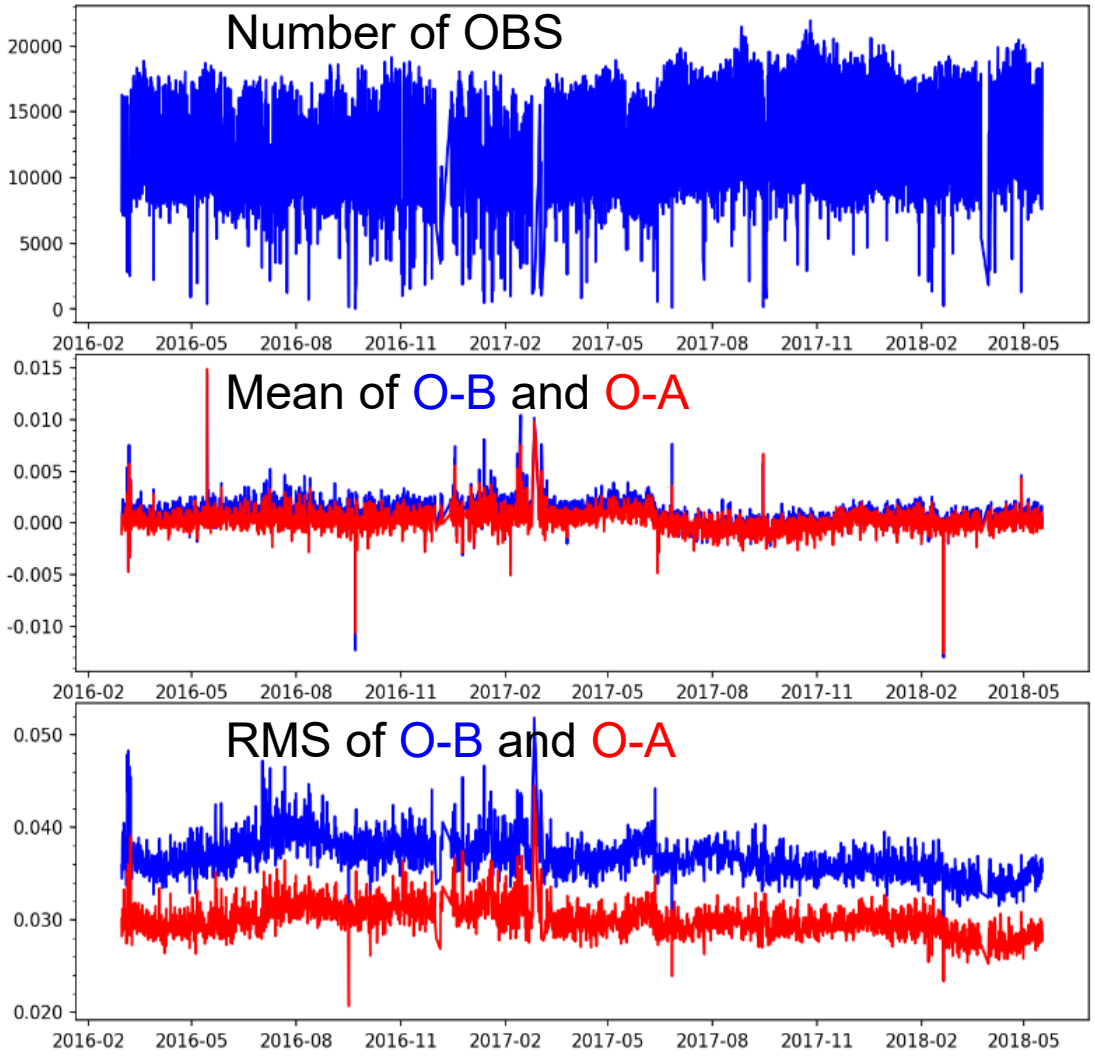
Zonal-mean cross-section of specific humidity 6h forecast



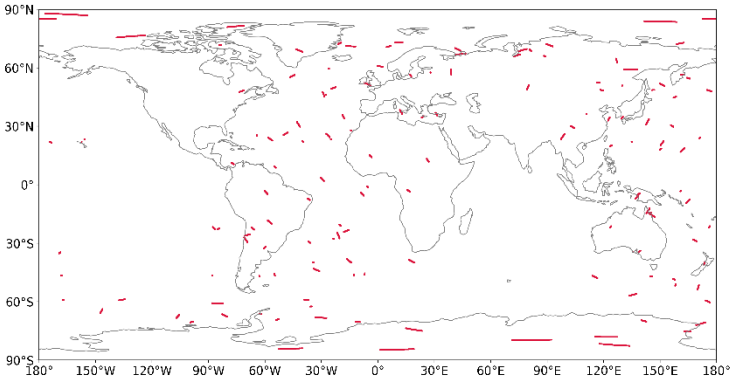


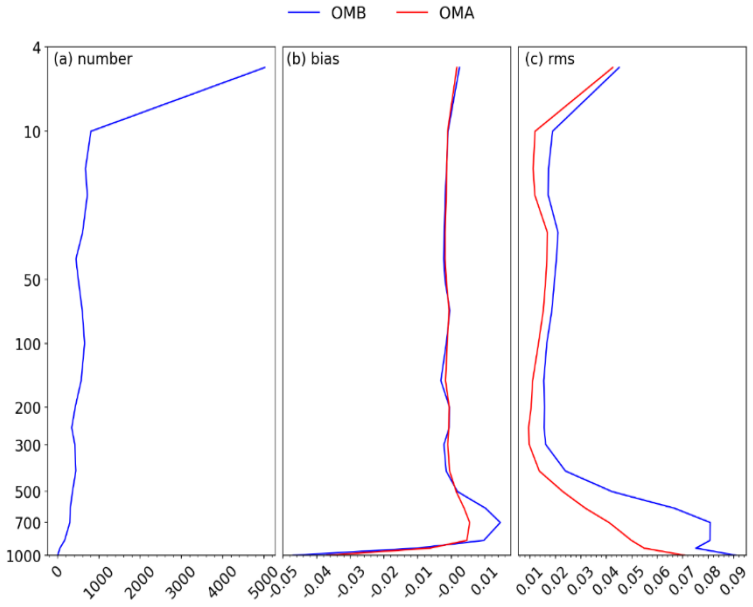
FY-3C GPS-RO were assimilated in CRA since March, 2016

- **GPS-RO bending angle were assimilated.**
- **The bias and RMS are stable.**

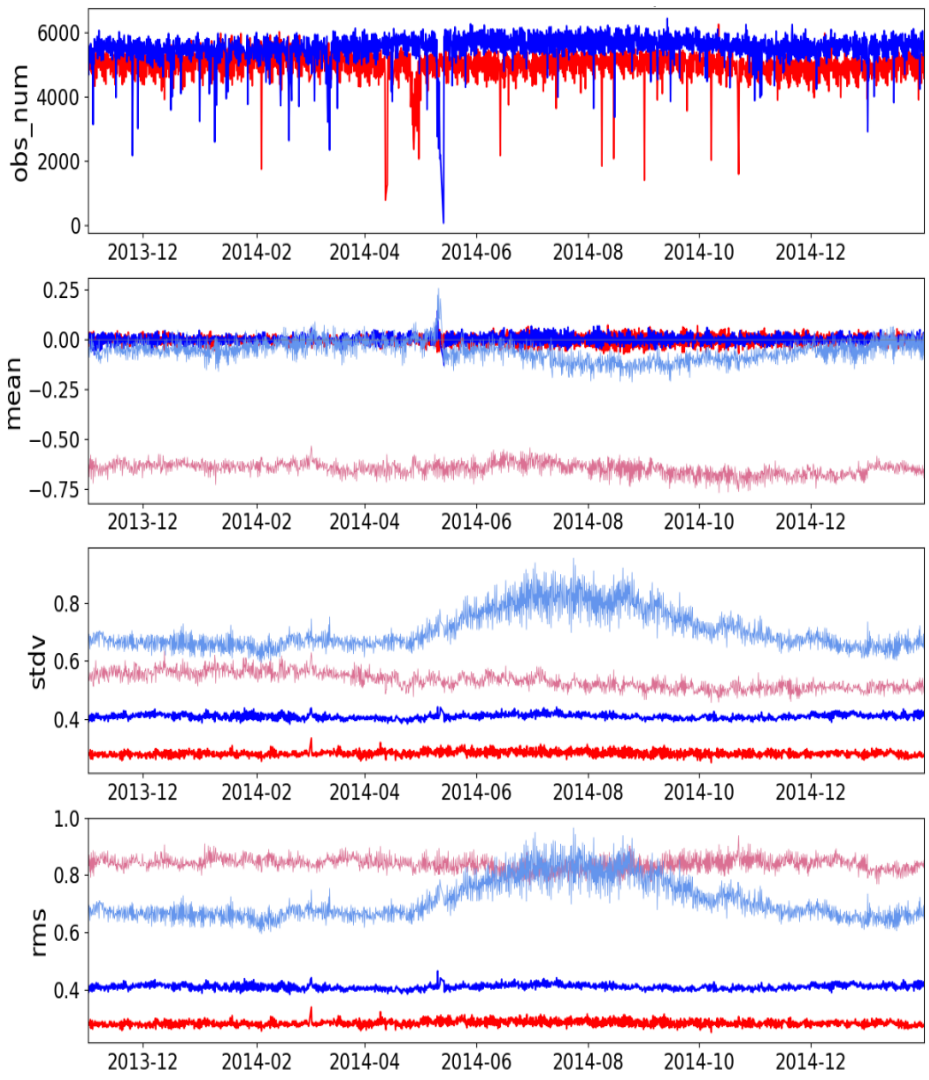


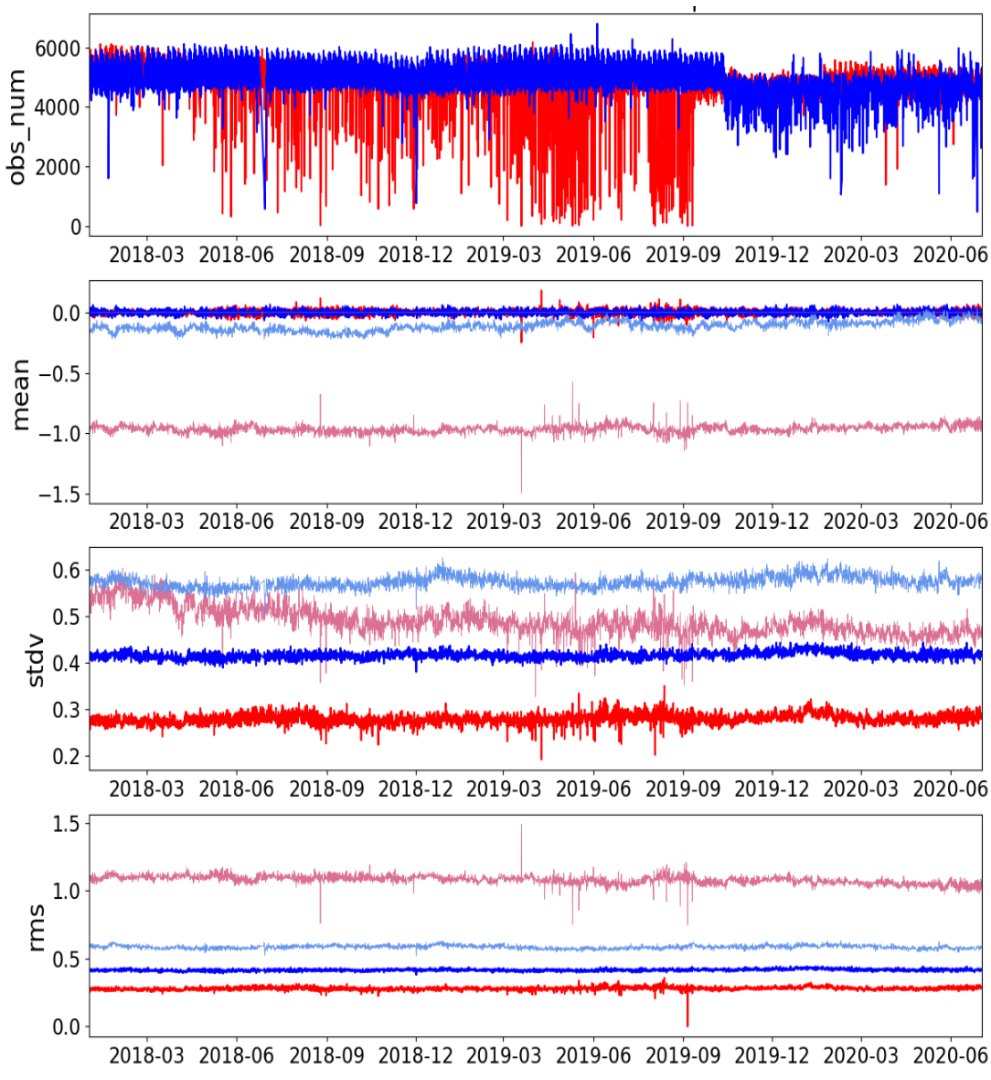
Spatial distribution within 6h time window
(2017-10-25 9-15UTC)





Evaluation of Reprocessed FY-3C/D MWTS against CRA





— MWTS2/FY3C CH3 OMB (with bias correction)
— MWTS2/FY3C CH3 OMB (without bias correction)
—ATMS/SNPP CH5 OMB (with bias correction)
—ATMS/SNPP CH5 OMB (without bias correction)

— MWTS2/FY3D CH3 OMB (with bias correction)
— MWTS2/FY3D CH3 OMB (without bias correction)
—ATMS/SNPP CH5 OMB (with bias correction)
—ATMS/SNPP CH5 OMB (without bias correction)

International NWP Communities

https://link.springer.com/journal/376/topicalCollection/AC_0e45b9611a5764787939afa59a5a8cbc/page/1

Meeting Summary

The First Fengyun Satellite International User Conference

Di Xian, Peng Zhang, Meng Fang, Chang Liu, Xu Jia

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Data Description Article

Fengyun Meteorological Satellite Products for Earth System Science Applications

Di Xian, Peng Zhang, Ling Gao, Ruijing Sun...

» Download PDF (3240KB) Pages 1-18

Original Paper

Growing Operational Use of FY-3 Data in the ECMWF System

Niels Bormann, David Duncan, Stephen English...

» Download PDF (3951KB) Pages 1-14

Original Paper

Insights into the Microwave Instruments Onboard the Feng-Yun 3D Satellite: Data Quality and Assimilation in the Met Office NWP System

Fabien Carminati, Nigel Atkinson, Brett Candy...

» Download PDF (2270KB) Pages 1-18

ECMWF

Table 1. FY-3 instruments assimilated in the operational ECMWF system.

Satellite	Launch	Instrument	Main impacts	Period of use
FY-3B (afternoon satellite, present ECT of 1600)	4 Nov 2010	MWHS-1	Mid- and upper-tropospheric humidity, dynamics	24 Sep 2014 to 1 Jun 2020[a]
FY-3C (morning satellite, present ECT of 0900)	23 Sep 2013	MWHS-2	Mid- and upper-tropospheric humidity, clouds, dynamics	Since 4 Apr 2016
		GNOS	Upper-tropospheric/lower- stratospheric temperature/dynamics	6 Mar 2018 to 17 May 2020[b]
FY-3D (afternoon satellite, present ECT of 1400)	14 Nov 2017	MWHS-2	See above	Since 2 Dec 2019
		MWRI	Total column water vapor, clouds, dynamics	Since 13 May 2020
		GNOS	See above	Activation planned 2021

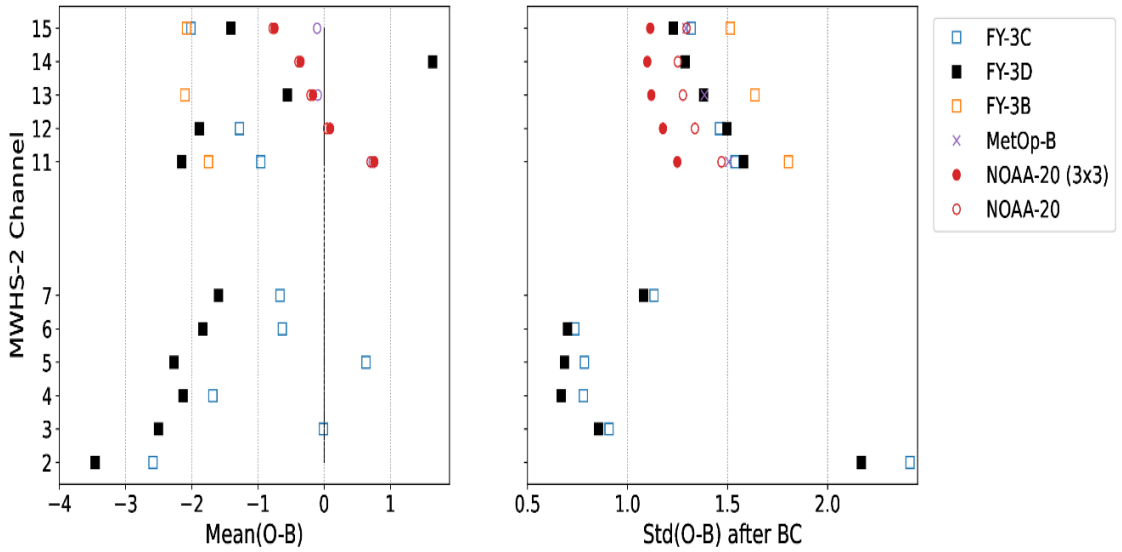
Satellite	Present orbit position (LTAN, approx.)	MW temperature sounder	MW humidity sounder	MW imager	IR broadband sounder or imager	IR hyper-spectral sounder
NOAA-15	19:00	A	X		X	
NOAA-18	21:00	A	X		X	
NOAA-19	17:00	A	A		P	
NOAA-20	13:30	A	A			A
Aqua	13:30	A	X			A
S-NPP	13:30	A	A			A
Metop-A	21:00	A	A		P	P
Metop-B	21:30	A	A		P	A
Metop-C	21:30	A	A			A
FY-3B	16:00	X	A	X		
FY-3C	10:00	X	A	P		
FY-3D	13:30	P & E	P & E	P & E		E
Meteor-M N2	20:30					E
DMSP-F17	18:30		A	A		
DMSP-F18	17:00		A	P		
GCOM-W1	13:30			A		
Coriolis	18:00			P		
GPM	Low-incl.		A	A		
Megha-Tropiques	Low-incl.		P			
Meteosat-8	41.5°E				A	
Meteosat-11	0°				A	
GOES-15	128°W				A	
GOES-16	75.2°W				A	
Himawari-8	140.7°E				A	
FY-4A	105°E					E

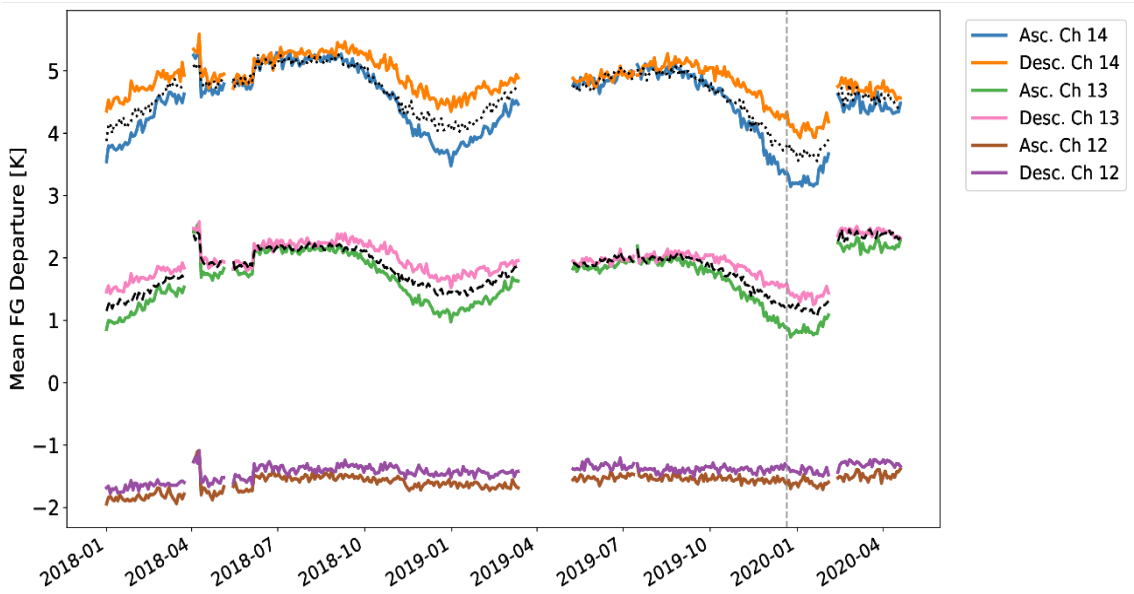
A-Assimilated,
P-Passively Monitored
E-Under Evaluation
X=Failed/withdraw

– All-sky treatment

FY-3 MW data quality assessment

The data show mostly stable characteristics, with expected noise performance and adequate accuracy.

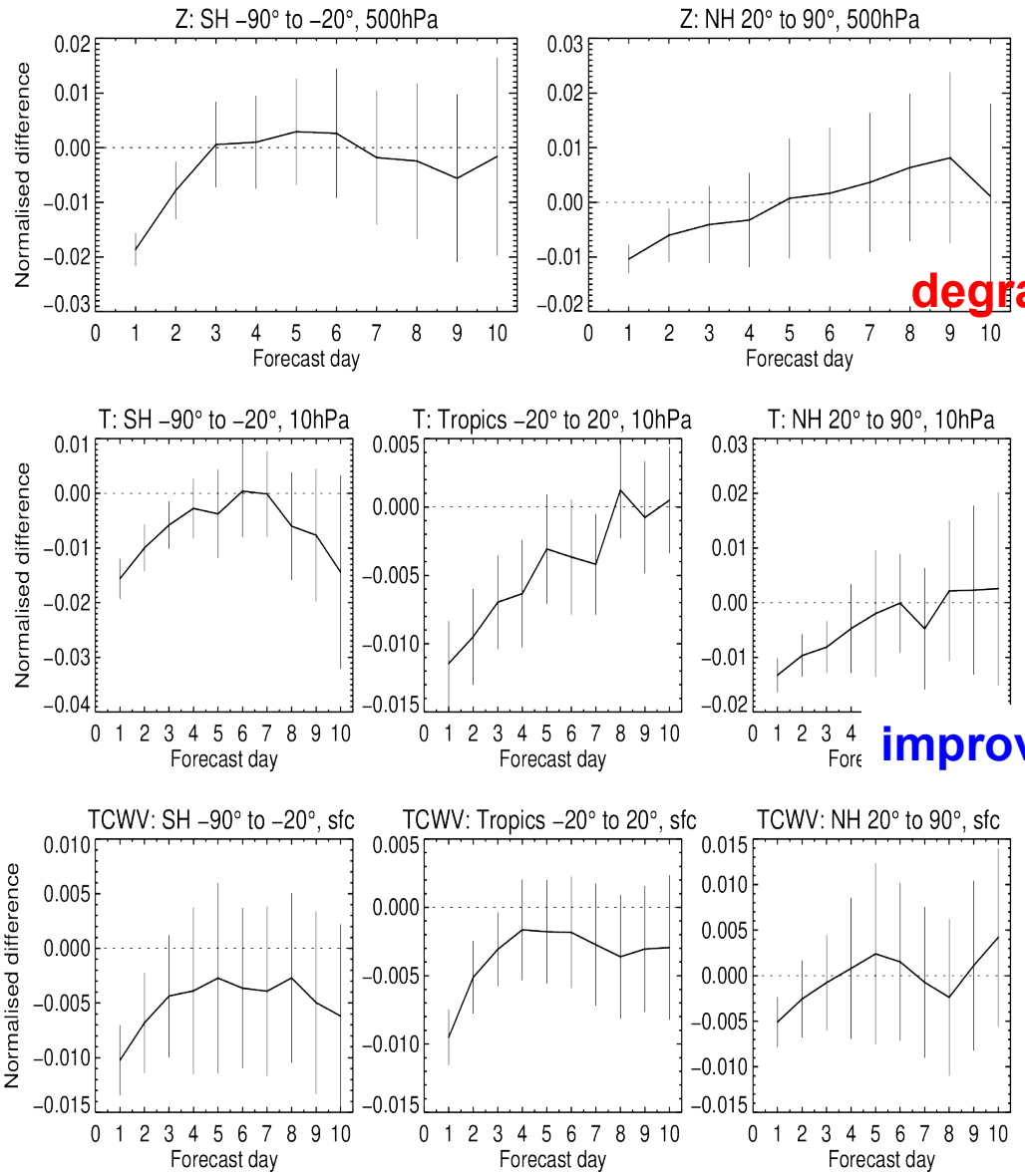




Bormann et al., 2021

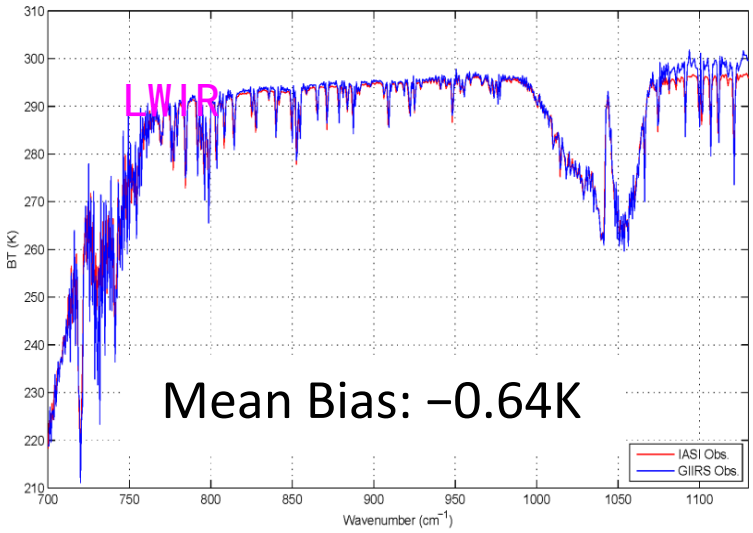
Combined impact of FY-3 data on ECMWF system

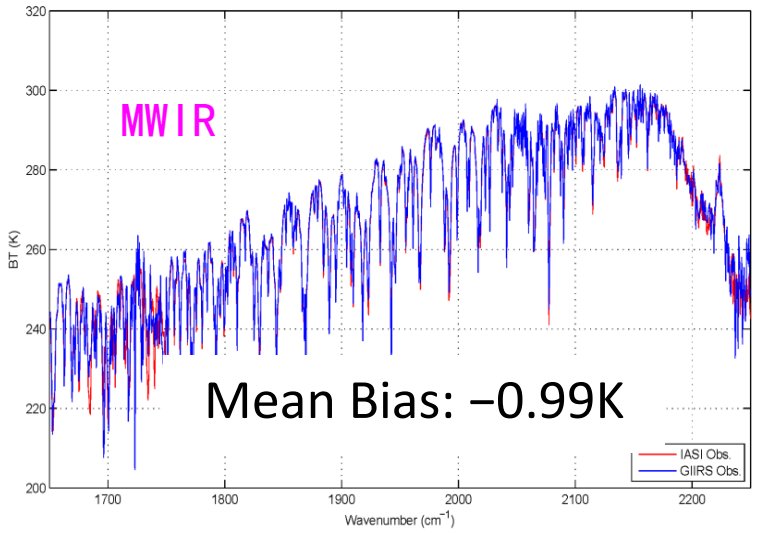
- An observing system experiment shows that the FY-3 instruments jointly contribute significantly to the forecast skill in the ECMWF system.
- Positive impact of up to 2% is seen for most variables out to the day 2 forecasts over hemispheric scales
- significant benefits for total column water vapour or in the stratosphere out to day 4



The initial evaluation results of GIIRS

- The on-orbit spectral resolution for LWIR and MWIR are 0.625cm^{-1} , better than the specified (0.8/1.6 cm^{-1}) , similar to NPP/CrIS;
- The NEDT for all the 1650 channels except some contaminated channels, generally is less than 0.1K, consistent with the specified;
- The comparisons of LWIR and MWIR with the counterpart channels from METOP-A/IASI shows that the calibration difference is about 0.64K and 0.99K separately, spectral difference is about 8ppm.



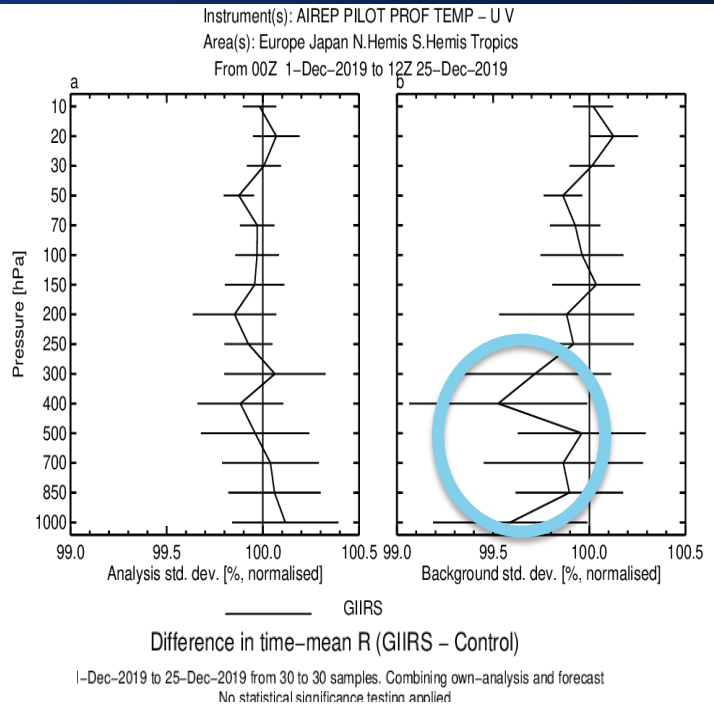


Spectrum Comparison with METOP/IASI

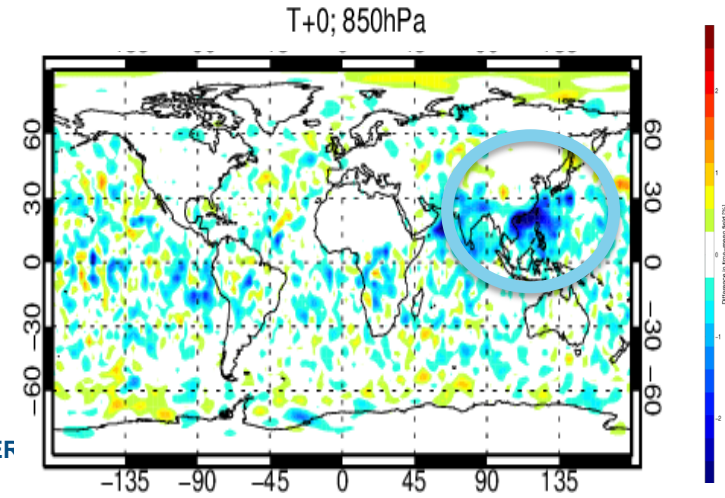
GIIRS progress and plans in ECMWF

- many channels are now useable.
- IFS is set up and several experiments are running, testing:
  - Channel selection
  - Spatial thinning
  - Observation errors
  - Cloud detection
- Early days for such a new observation type, so mixed results initially, but a project has just started with EUMETSAT to take this further and converge on an optimal assimilation strategy.

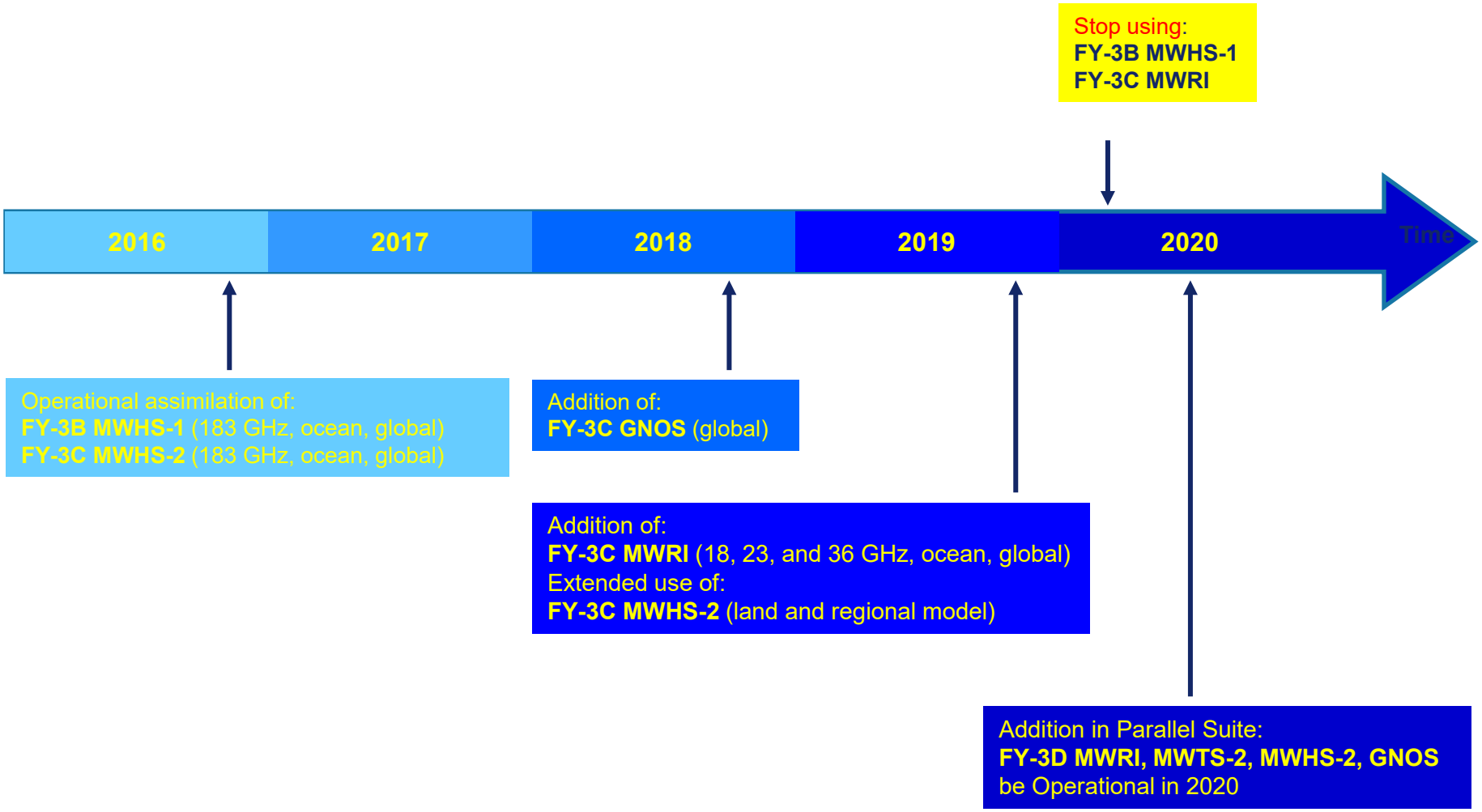
FG fit to winds improved



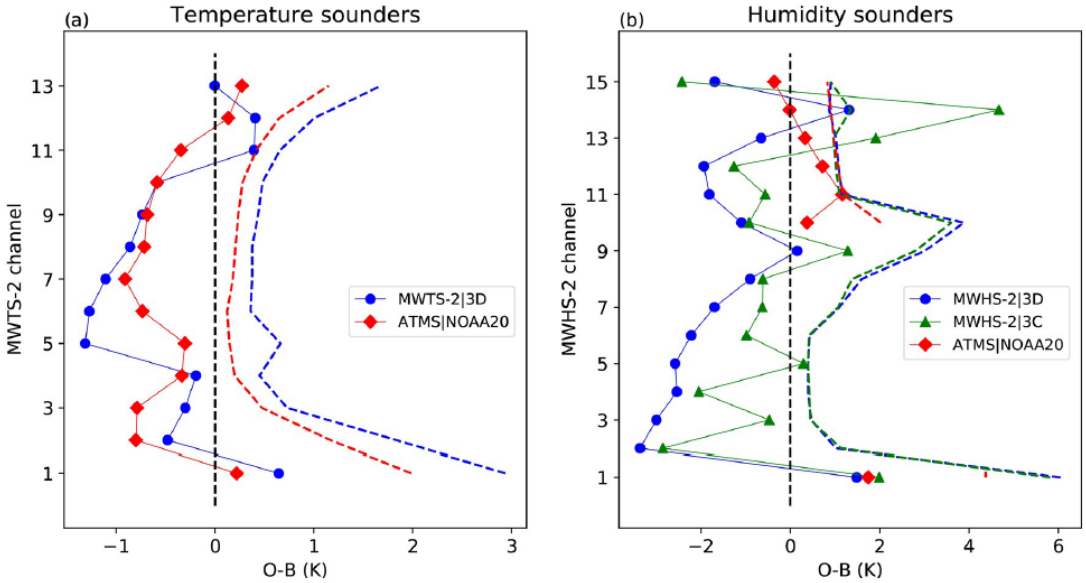
Mean change in T and R over GIIRS domain. RMSE ~neutral.



UK Met Office



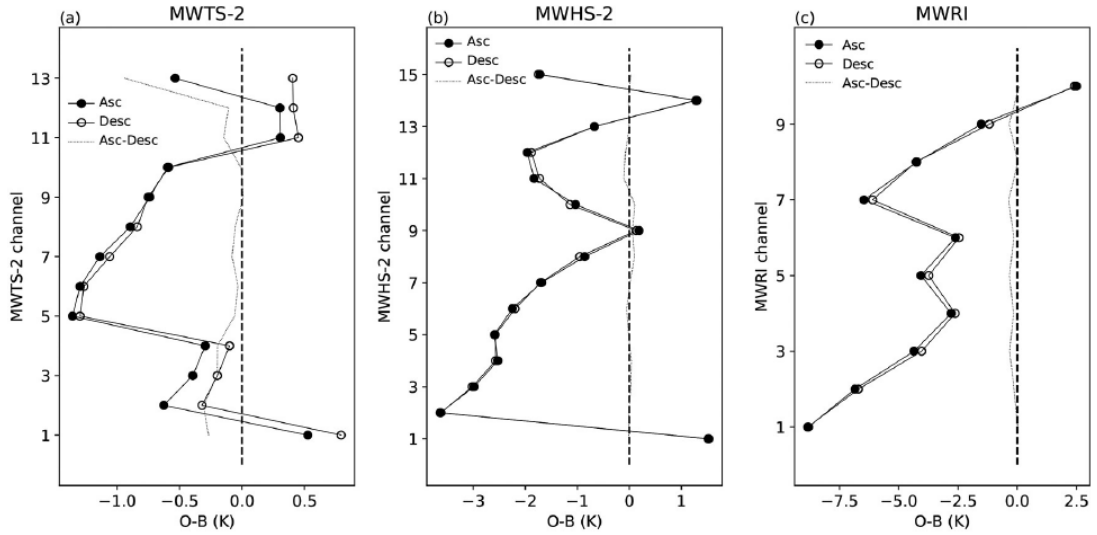
Impact of MWHS-1 & MWHS-2



Carminati et al., 2021

(a) Mean background departure (O-B) and standard deviation of O-B for FY-3D MWTS-2 (blue) and NOAA-20 ATMS (red) low-scattering oceanic scenes averaged between 15 June and 15 September 2019. Solid lines show the mean and dashed lines the standard deviation. (b) As in (a) but for FY-3D MWHS-2 (blue), FY-3C MWHS-2 (green), and NOAA-20 ATMS (red).

The combined impact of FY-3B MWHS-1 and FY-3C MWHS-2 was > 2% in January 2020.

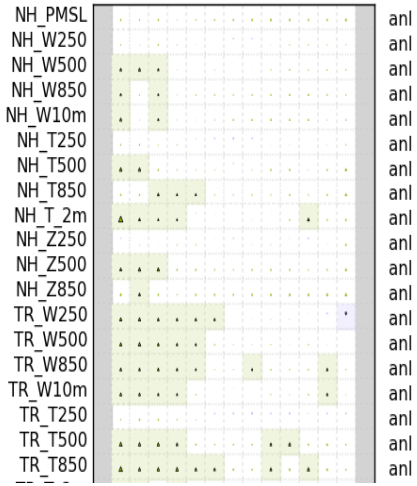


(a) FY-3D MWTS-2 mean background departure from the ascending node (filled circles) and descending node (open circles) for low-scattering oceanic scenes averaged over August 2019. The gray line shows the difference, i.e., O-B ascending minus O-B descending. (b) As in (a) but for FY-3D MWHS-2. (c) As in (a) but for FY-3D MWRI.

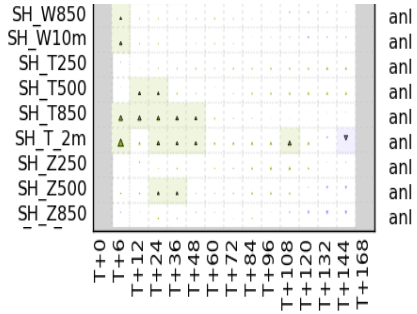
Assimilation of FY-3D instruments (2020)

Upward-pointing green triangles denote improvement and downward-pointing purple triangles denote degradation. Shading shows significant changes

RMSE difference against control

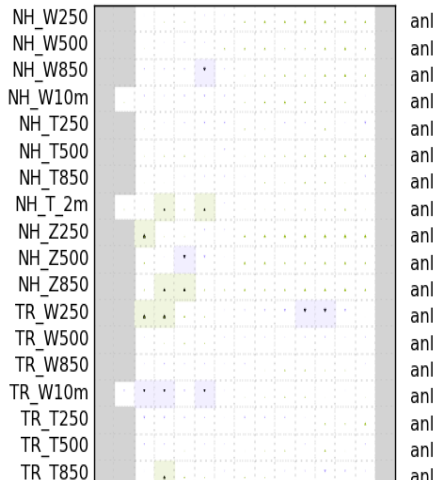


0.1% reduction in RMSE when assimilating MWTS-2 and MWHS-2.

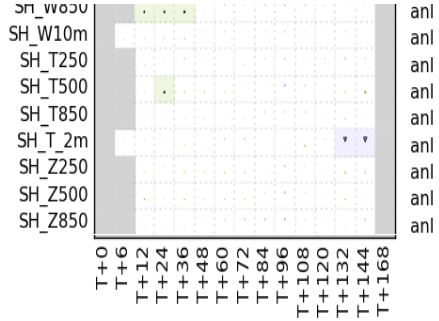


MWTS-2 + MWHS-2

RMSE difference against control

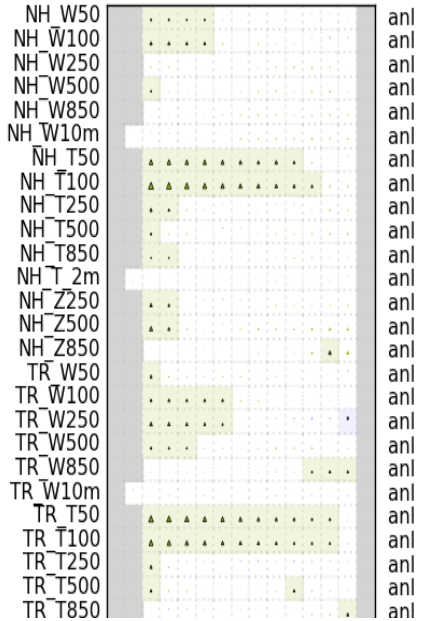


Neutral change in RMSE when assimilating FY-3D MWRI.

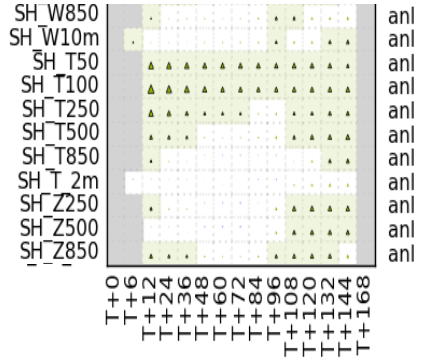


MWRI

RMSE difference against control



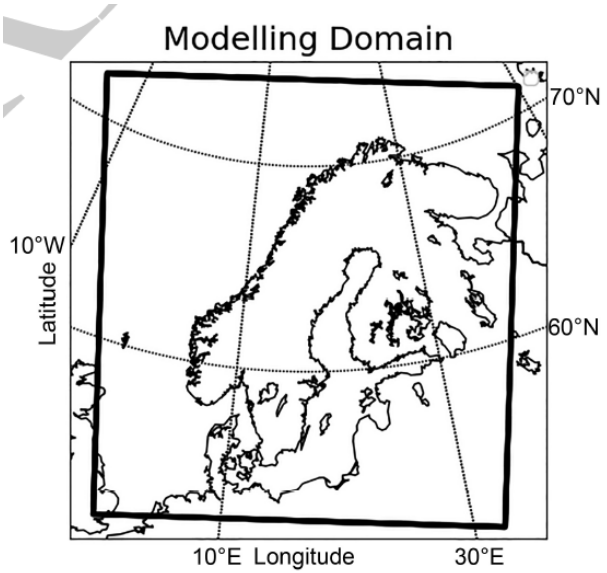
0.19% reduction in RMSE when assimilating GNOS data from FY-3D (data above 40km excluded).

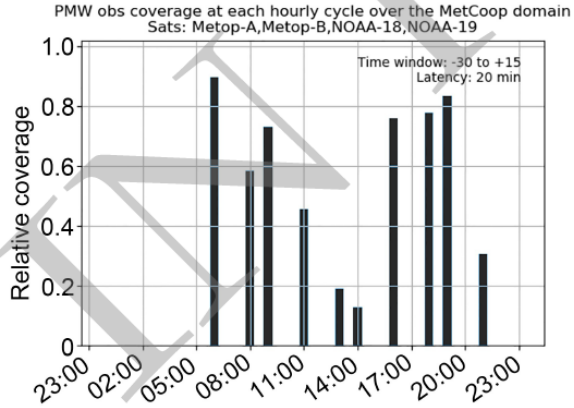


GNOS

Swedish Meteorological and Hydrological Institute

Lindskog et al., 2021





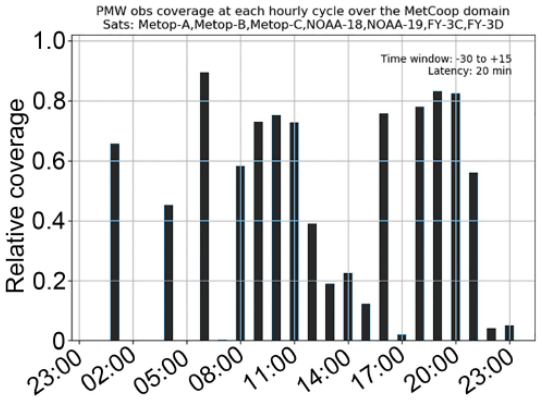
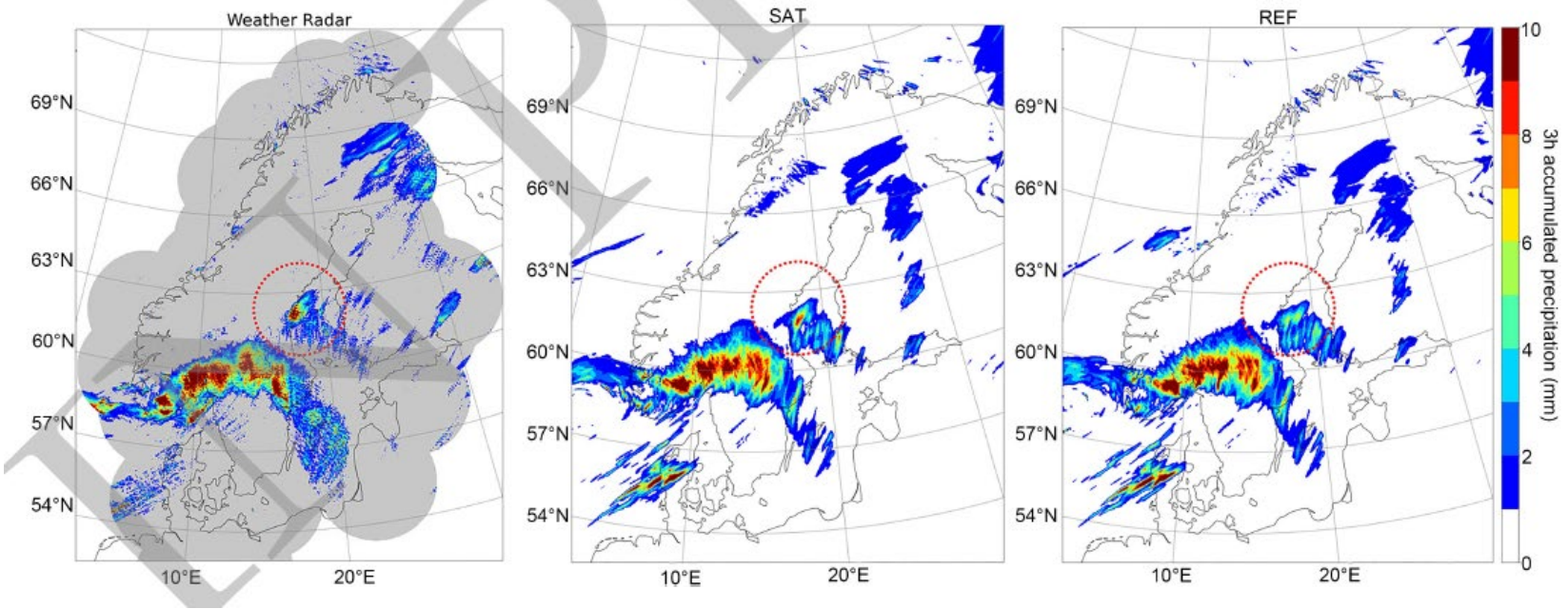
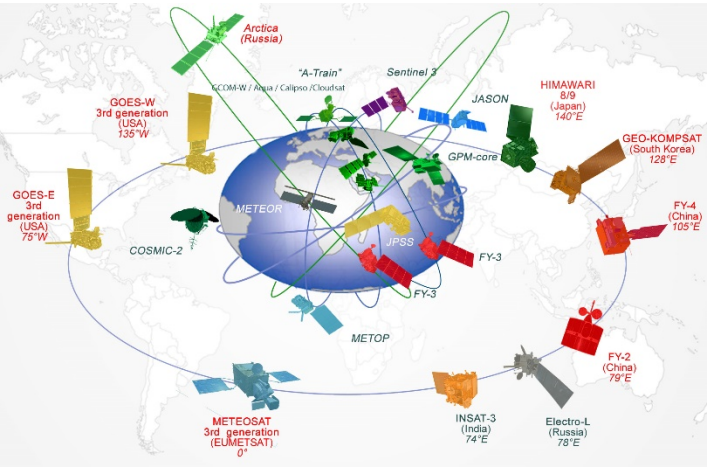


Fig. 1. MetCoOp modelling domain used in this study.





Thanks for your attention.