

CMA Global Reanalysis (CRA-40): Status and Plan

Zhiquan Liu

**and many scientists from NMIC, CAMS,
NMC, NCC, NSMC, NUIST, IAP, BNU**



国家气象信息中心
National Meteorological Information Center

Outline

- **Background**
- **Progress in the past two more years**
 - **T639/GSI based reanalysis experiments (2015)**
 - **GFS/GSI based reanalysis experiments (2016)**
 - **Implementation of the NRT system (2016)**
- **Future Plan**



Outline

- **Background**
- Progress in the past two more years
 - T639/GSI based reanalysis experiments
 - GFS/GSI based reanalysis experiments
 - Implementation of the NRT system
- Future Plan



Existing Global Reanalyses

- **US, ECMWF, JMA already produced several rounds of global reanalyses**

	Reanalysis	Producer	Period	Resolution	Assimilation
1 st Generation	NASA/DAO	NASA/DAO	1980-1995	2×2.5L20	3S-OI+IAU
	NCEP/NCAR	NCEP+NCAR	1948-	T62L28	3DVAR SSI
	ERA-15	ECMWF	1979-1993	T106L31	3D-OI
2 nd Generation	NCEP/DOE	NCEP+DOE	1979-	T62L28	3DVAR SSI
	ERA-40	ECMWF	1957.9-2002.8	T _L 159L60	3DVAR
	JRA-25	JMA-CRIEPI	1979-	T106L40	3DVAR
3 rd Generation	ERA-Interim	ECMWF	1979-	T _L 255L60	4DVAR
	CFSR	NCEP	1979-	T382L64	3DVAR GSI
	MERRA	NASA	1979-2010	1/2×2/3L72	3DVAR GSI
	JRA-55	JMA	1957.12-2012	T _L 319L60	4DVAR
Other	20CR	NOAA-CIRES	1871-2008	T62L28	EnKF w/ P _{sfc}
	MERRA-AERO	NASA	2000-	50kmL72	Aerosol DA
	MACC	ECMWF	2003-	T _L 255L60	4DVAR w/ Chemistry
4 th Generation	ERA5	ECMWF	1979-	T _L 639L137	Ensemble of 4DVAR



Reanalysis papers are highly cited → broad applications

- Year Published** **The NCEP/NCAR 40-year reanalysis project**
[E Kalnay, M Kanamitsu, R Kistler...](#) - Bulletin of the ..., 1996 - journals.ametsoc.org
Abstract The NCEP and NCAR are cooperating in a project (denoted “**reanalysis**”) to produce a 40-year record of global analyses of atmospheric fields in support of the needs of the research and climate monitoring communities. This effort involves the recovery of land ...
Cited by [21765](#) Related articles All 25 versions Web of Science: [13838](#) Cite Save
- 1996, US NCEP/NCAR**
- The NCEP climate forecast system reanalysis**
[S Saha, S Moorthi, HL Pan, X Wu...](#) - Bulletin of the ..., 2010 - search.proquest.com
Abstract To use the same model and data assimilation over a very long period was the great advance during the 1990s, because gridded datasets available before 1995 had been created in real time by ever-changing models and analysis methods, even by hand ...
Cited by [1710](#) Related articles All 21 versions Web of Science: [1117](#) Cite Save
- 2010, NOAA CFSR**
- MERRA: NASA's modern-era retrospective analysis for research and applications**
[MM Rienecker, MJ Suarez, R Gelaro...](#) - Journal of ..., 2011 - journals.ametsoc.org
Abstract The Modern-Era Retrospective Analysis for Research and Applications (**MERRA**) was undertaken by **NASA's** Global Modeling and Assimilation Office with two primary objectives: to place observations from **NASA's** Earth Observing System satellites into a ...
Cited by [1735](#) Related articles All 6 versions Web of Science: [1238](#) Cite Save
- 2011, NASA MERRA**
- [HTML] **The ERA-Interim reanalysis: Configuration and performance of the data assimilation system**
[DP Dee, SM Uppala, AJ Simmons...](#) - Quarterly Journal of ..., 2011 - Wiley Online Library
... The organisation of this **paper** reflects these three categories, with a section devoted to the description of each. In section 5 we summarise our evaluation of the performance of **ERA-Interim**, with a particular focus on progress made since ERA-40. ...
Cited by [5960](#) Related articles All 14 versions Web of Science: [4065](#) Cite Save More
- 2011, ECMWF ERA-Interim**

CMA global & regional reanalysis

- Late 2013, CMA decided to start global and regional reanalysis efforts
 - NMIC leads global reanalysis
 - Obtained funds for a 4-year (2015-2018) project (行业专项重大项目)
 - 7 institutes involved in the project
 - CAMS leads East Asia regional reanalysis

Late 2014, CMA determined

3 Core Projects for Innovation (2014-2020)

1

**High-Resolution Data Assimilation
and NWP**

NMC、CAMS

2

**Sub-seasonal to Seasonal climate
prediction and modeling system**

NCC、CAMS

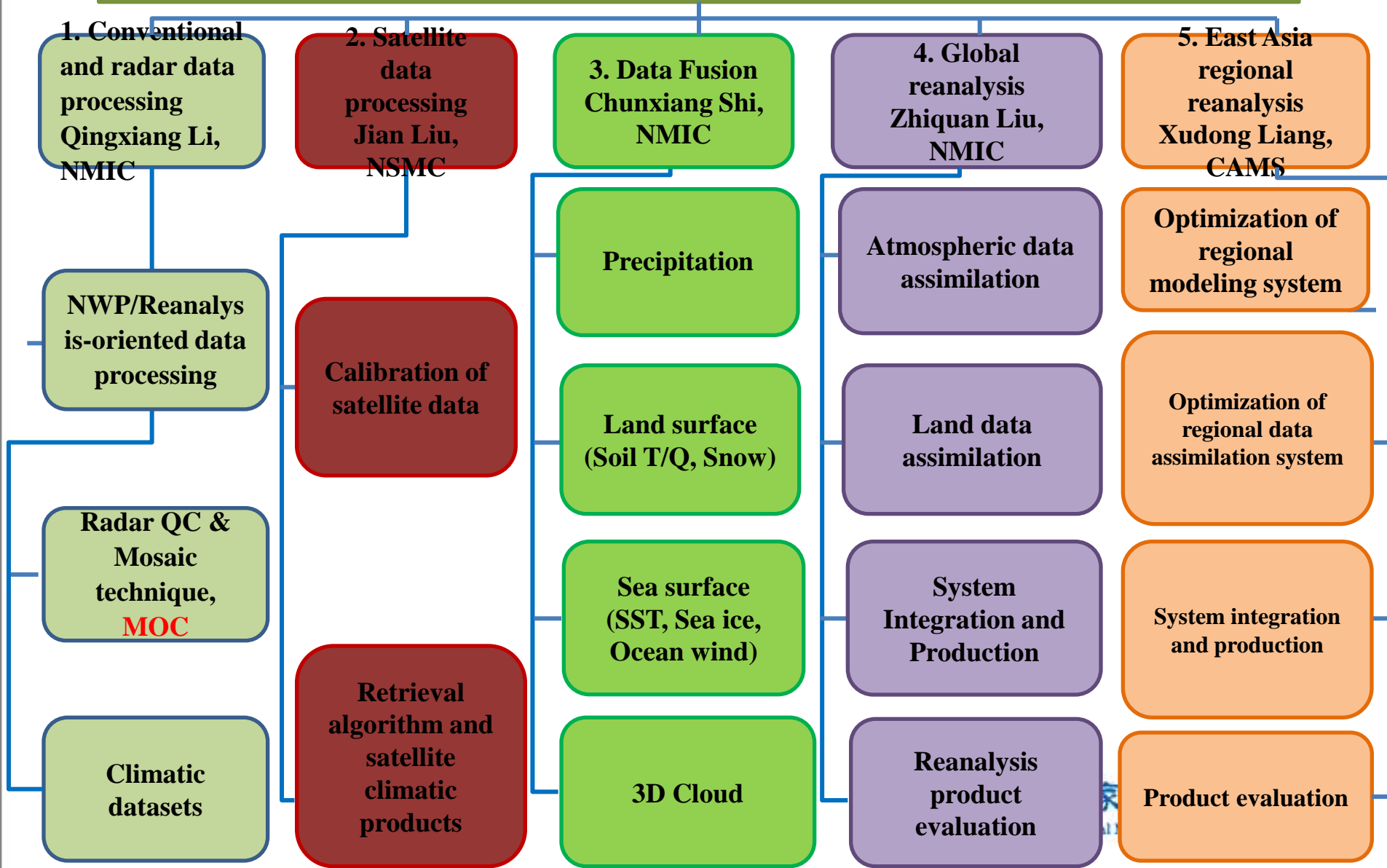
3

**QC, Fusion and Reanalysis of
Meteorological Observations**

NMIC、CAMS

Quality Control, Fusion, and Reanalysis of Meteorological Observations

Zhiquan Liu & Zijiang Zhou, NMIC



Why another reanalysis?

- Prompt service capability of NMIC (part of its function like NOAA/NCDC) by collecting more historical observations via reanalysis project and producing gridded reanalysis product
- Improve NCC's capability for climate monitoring/prediction with more timely reanalysis product
 - NCC current climate monitoring relies on the 1st generation NCEP/NCAR reanalysis
- Foster the optimal assimilation of observations at NMC, especially from Chinese observing networks
- Many other scientific/societal benefits ...



Goal of CMA 40-year Global Reanalysis (CRA-40)

Produce 40-year datasets (1979-2018) :

- Ingested observations
- Reanalysis datasets: CMA Reanalysis (~30km, 6 hourly)
- **Obs. feedback datasets** : departure from analysis & 6h forecast
- **Reanalysis uncertainty** : from EnKF ensembles

Will become an operational system : CMA Re-Analysis System - CRAS

- Continuously running in near real time for climate monitoring

Outline

- Background
- **Progress in the past two more years**
 - **T639/GSI based reanalysis experiments (2015)**
 - GFS/GSI based reanalysis experiments (2016)
 - Implementation of the NRT system (2016)
- Future Plan



T639/GSI-based reanalysis experiment

- CMA operational NWP (when proposed reanalysis in 2014)
 - CMA's global NWP operation is **T639** (based on an old version of ECMWF model, ~1996 version) plus an **old GSI-3DVAR** (2006 version)
 - Ingest limited observations (Conv., ATOVS, AMV)
- 2014 proposed strategy for CMA reanalysis
 - **Not touch T639 model, but update GSI to the latest version**
 - Binary format observation to PrepBUFR/BUFR
- NMIC was able to produce a 2.5-year experimental reanalysis in 2015
 - **Using T639+GSI-V3.3 and NCEP GDAS BUFR observations**
 - Compared to re-run operational T639+GSI



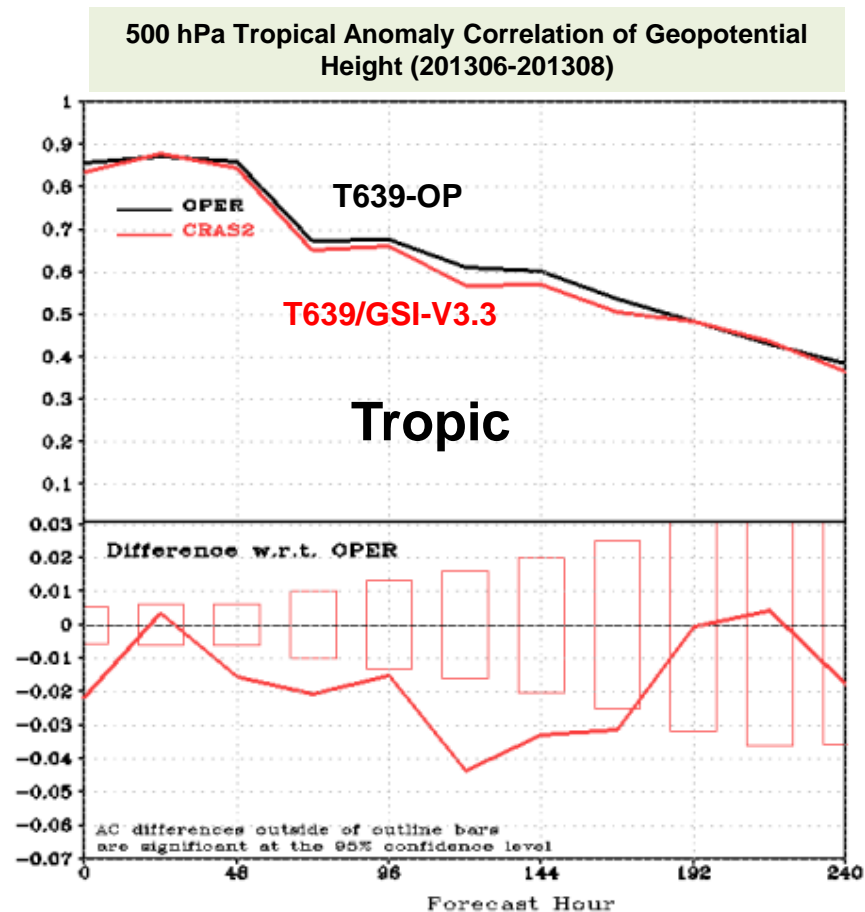
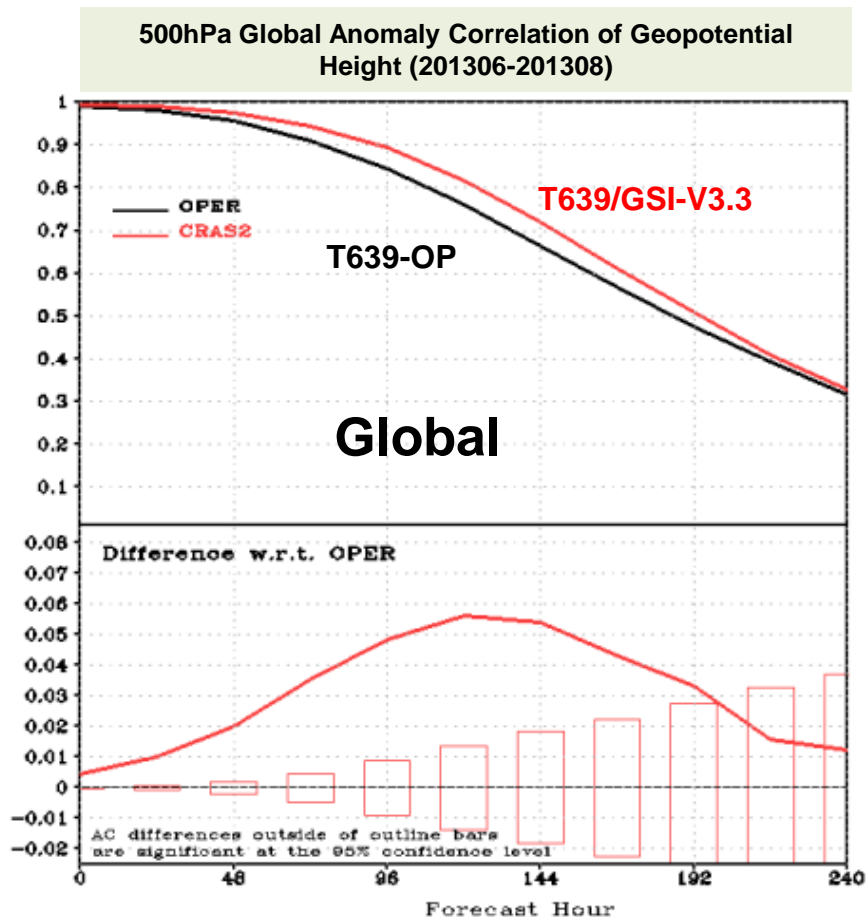
Configuration difference: OP vs. Exp (T639/GSI-V3.3)

	Operation	Exp (T639/GSI-V3.3)
GSI	GSI2006 version	GSI-V3.3
Observation	<p>Conv. OBS (CMA binary format): Radiosonde, SHIP/BUOY(Ps,T,Q,W), SYNOP(Ps), AirCFT</p> <p>AMUA: NOAA15, 18</p> <p>AMUB/MHS: NOAA15, 16, 18</p> <p>NO GPSRO SatWind VIS/IR: JMA, EUMET WV : MODIS Other: NO</p>	<p>Conv. OBS (GDAS PrepBUFR): Radiosonde, SHIP/BUOY(Ps,T,Q,W), SYNOP(Ps), little AirCFT, METAR(ps)</p> <p>AMUA: NOAA15, 16, 18, 19 METOP-A, METOP-B</p> <p>AMUB/MHS: NO USE</p> <p>GPSRO SatWind VIS/IR: JMA, EUMET, GOES, MODIS WV: JMA, EUMET, GOES, MODIS Other: ASCAT wind, VADWND</p>
Background & obs. error	Obs. error: from binary obs. input Bk. error: from operational file	Obs. error: from prepBufr Bk. error: converted from OP
Other	/	Strong dynamic constraint (TLNMC)

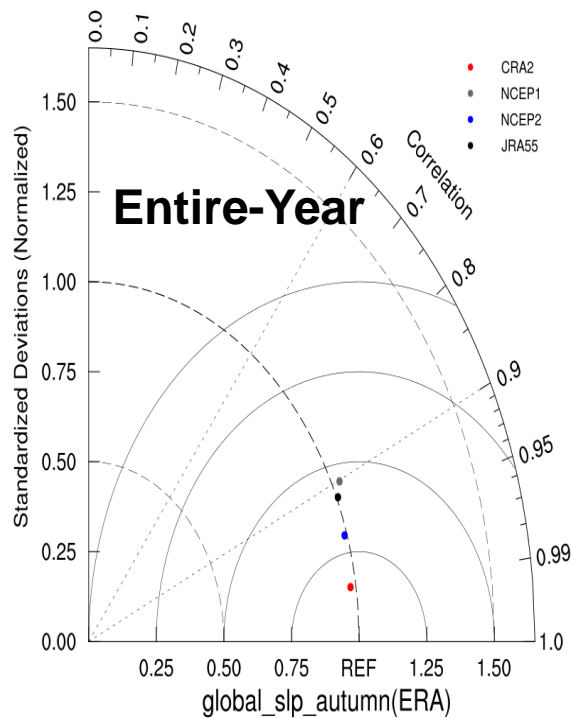
10d forecast evaluation against NCEP FNL

500hPa anomaly correlation of geopotential height

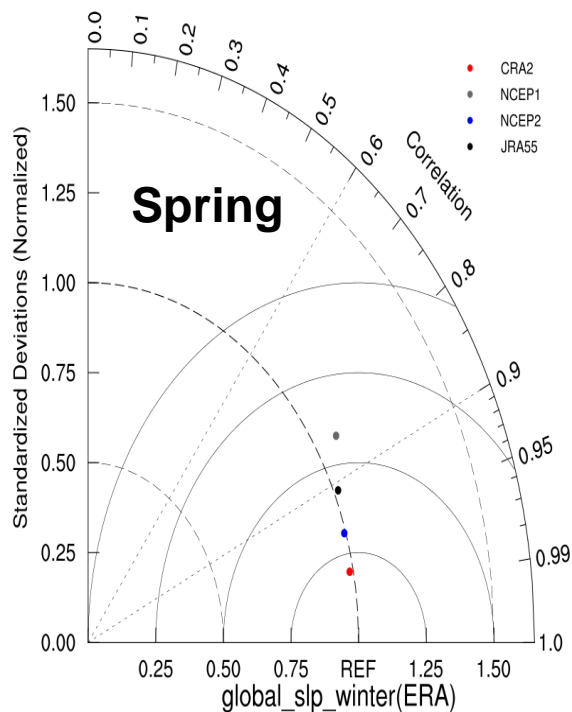
Improved except tropical zone



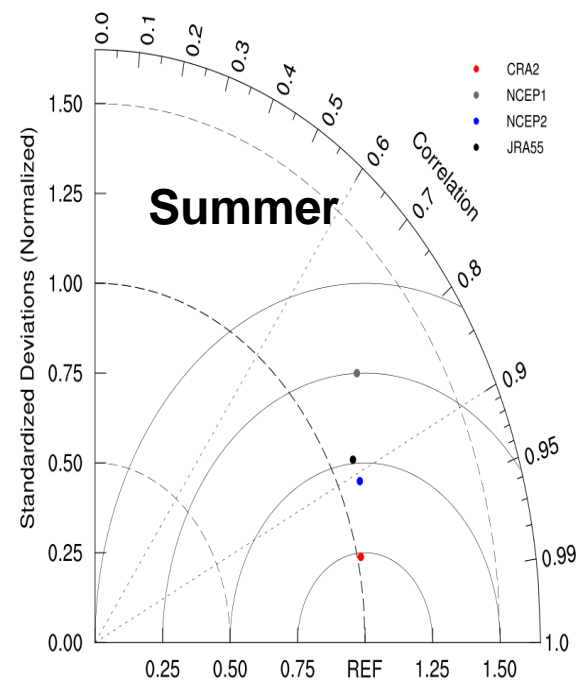
global_slp_year(ERA)



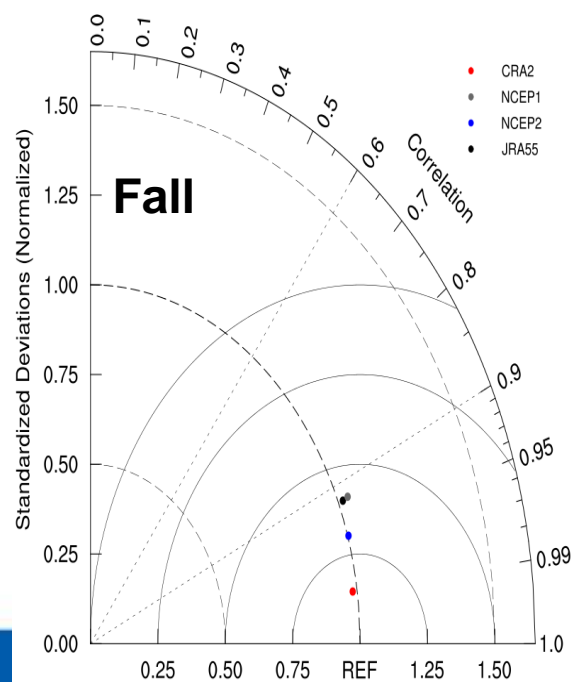
global_slp_spring(ERA)



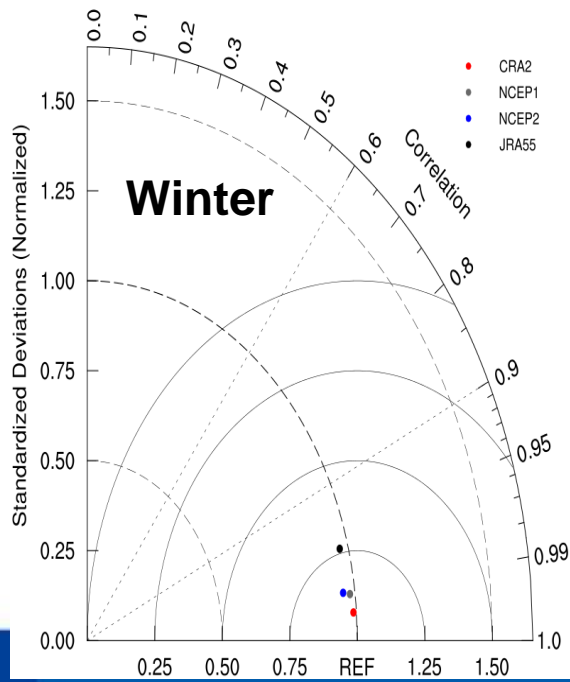
global_slp_summer(ERA)



global_slp_autumn(ERA)



global_slp_winter(ERA)



**NCC climatic evaluation:
Tyler-diagram, use ERA-I
as reference field**



国家气象信息中心
National Meteorological Information Center

Evaluation by National Climate Center

Climate Indices

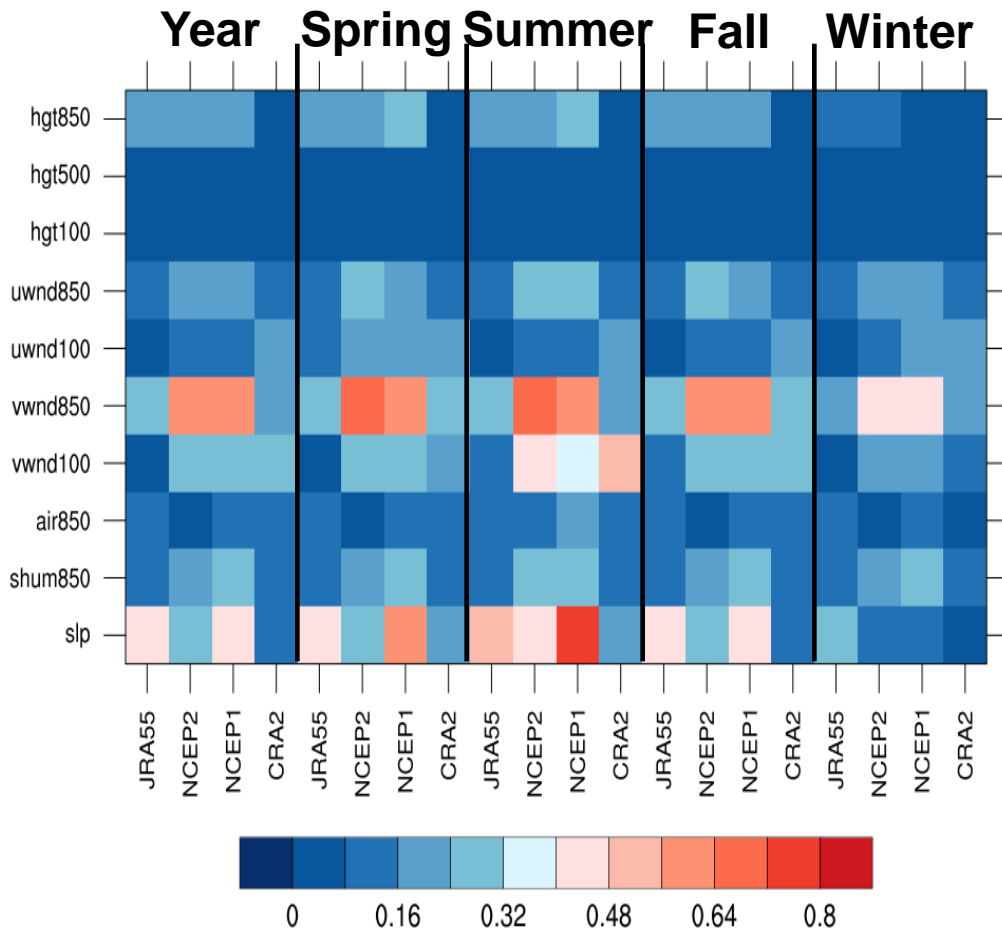
Global Mean Quantities

气候指数		气候变量全球平均指标				
		全年	春季	夏季	秋季	冬季
太平洋-北美型遥相关	■	■	■	■	■	■
西太平洋型遥相关	■	■	■	■	■	■
西大西洋型遥相关	■	■	■	■	■	■
东大西洋型遥相关	■	■	■	■	■	■
欧亚型遥相关	■	■	■	■	■	■
南方涛动	■	■	■	■	■	■
西太平洋副高	■	■	■	■	■	■
东亚夏季风	■	■	■	■	■	■
南海夏季风	■	■	■	■	■	■
		500hPa高度	■	■	■	■
		850hPa比湿	■	■	■	■
		海平面气压	■	■	■	■
		850hPa温度	■	■	■	■
		850hPa纬向风	■	■	■	■
		850hPa经向风	■	■	■	■
		CRA好	■	■	■	■
		NCEP好	■	■	■	■
		接近	■	■	■	■

ERA-Interim as reference : compare CRA with NCEP1, which is currently used in NCC climate monitoring

Red: CRA better than NCEP1

Blue: NCEP1 better than CRA (only for SOI)



CRA closer to ERA for hgt850/slp

CRA worse for vwnd100 in Summer time

Distance to ERA-I derived from Tyler-diagram Comparison among JRA55, NCEP1, NCEP2, CRA

Summed distance for different variables

		JRA55	NCEP2	NCEP1	CRA2
Year	年	1.28	2.06	2.30	1.24
Spring	春	1.34	2.14	2.58	1.31
Summer	夏	1.49	2.52	2.94	1.60
Fall	秋	1.32	2.08	2.28	1.28
Winter	冬	1.04	1.50	1.58	1.02
Average	平均	1.29	2.06	2.33	1.29

**CRA closer to ERA than JRA55/NCEP1-2 for year/spring/fall/winter,
JRA55 closer to ERA than CRA in Summer time**

**Overall: CRA better than NCEP1&2,
Similar to JRA55**



国家气象信息中心
National Meteorological Information Center

Encouraging results but issues remain

- **Large T bias in higher levels**
- **Worse scores over tropical region.**
- **Assimilated NCEP GDAS observations, not NMIC-processed observations.**



Outline

- Background
- **Progress in the past two more years**
 - T639/GSI based reanalysis experiments (2015)
 - **GFS/GSI based reanalysis experiments (2016)**
 - Implementation of the NRT system (2016)
- Future Plan



GFS vs. T639 (with same GSI-V3.3 and GDAS obs): score for 6-month run

	GFS	T639
Observation	GDAS	GDAS
System	GFS/GSI 3DVar	T639/GSI-V3.3 3DVar
Resolution	T _L 574	T _L 639

Score card for GFS/GSI compared with T639/GSI

Domain	Parameter	Level	Anomaly Correlation					RMS Error						
EASI	RH	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		500	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		850	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	UWND	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	VWND	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	TEMP	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	HGT	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		850	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
NH	RH	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		500	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		850	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	UWND	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	VWND	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	TEMP	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	HGT	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		850	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
SH	RH	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		500	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		850	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	UWND	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	VWND	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	TEMP	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	HGT	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		850	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
TRO	RH	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		500	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		850	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	UWND	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	VWND	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	TEMP	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		700	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	HGT	200	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		850	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲

Red: GFS/GSI better than T639/GSI

Green: GFS/GSI worse than T639/GSI

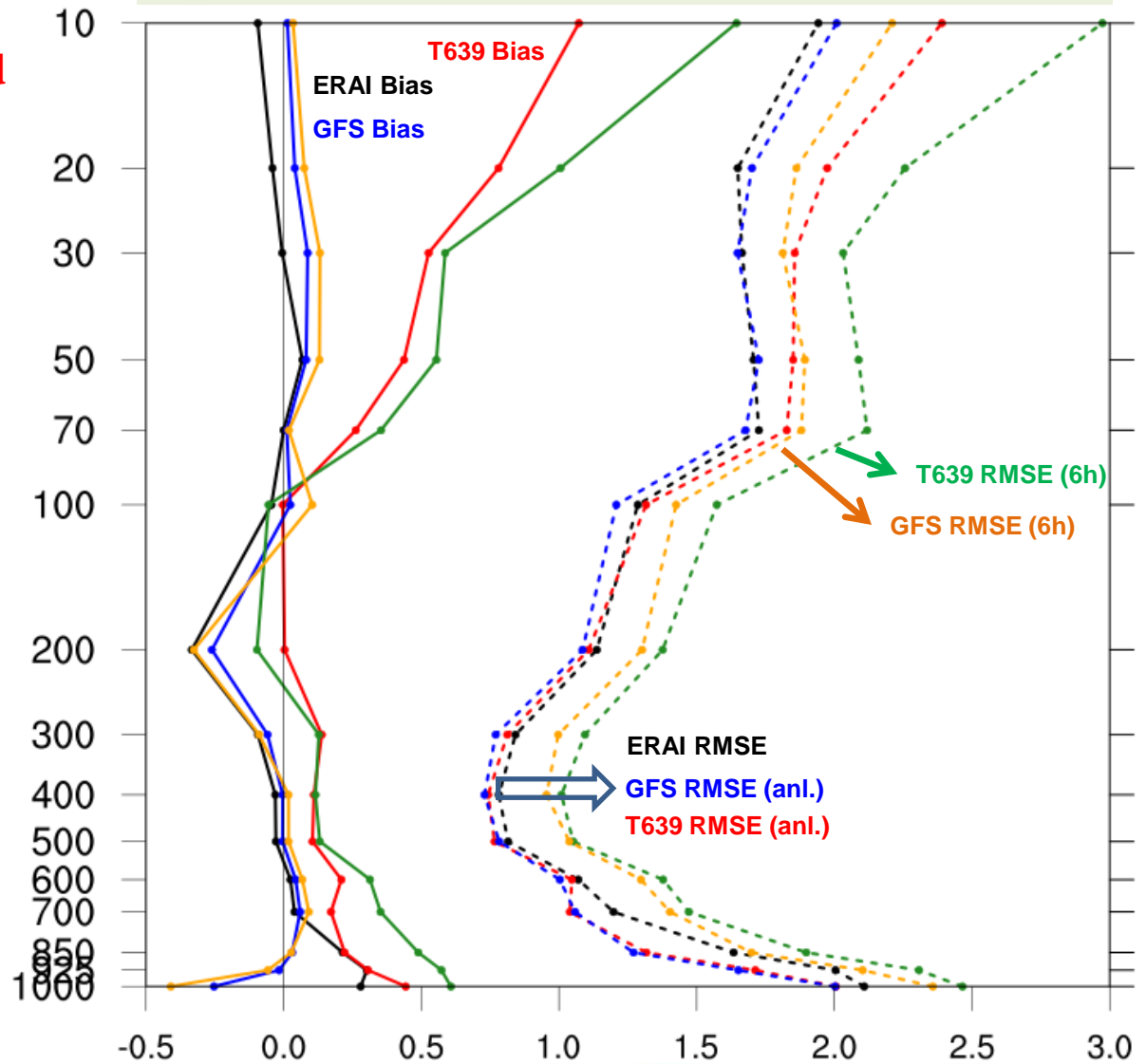
GFS is significantly better than T639.

Not surprised, because T639 is based on a 20-years old version of ECMWF model!

▲ : Far better ▲ : Better ■ : Better but not significant ■ : Equality
▼ : Far worse ▼ : Worse ■ : Worse but not significant

Evaluation against radiosonde observation (temperature)

Global average from Jun 2013 to Jun 2014



- **High-level T bias disappeared**

- **Analysis of GFS:**

Smaller RMSE than T639

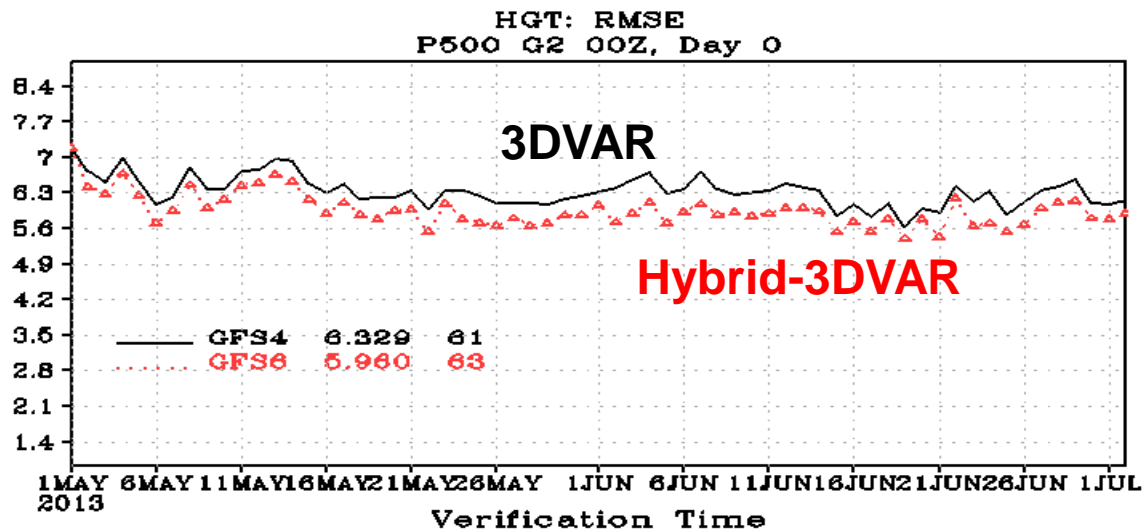
(even ERAI)

- **6h forecast of GFS:**

Much smaller RMSE than

T639.

500 hPa geopotential height analysis RMSE w.r.t. ERA-Interim

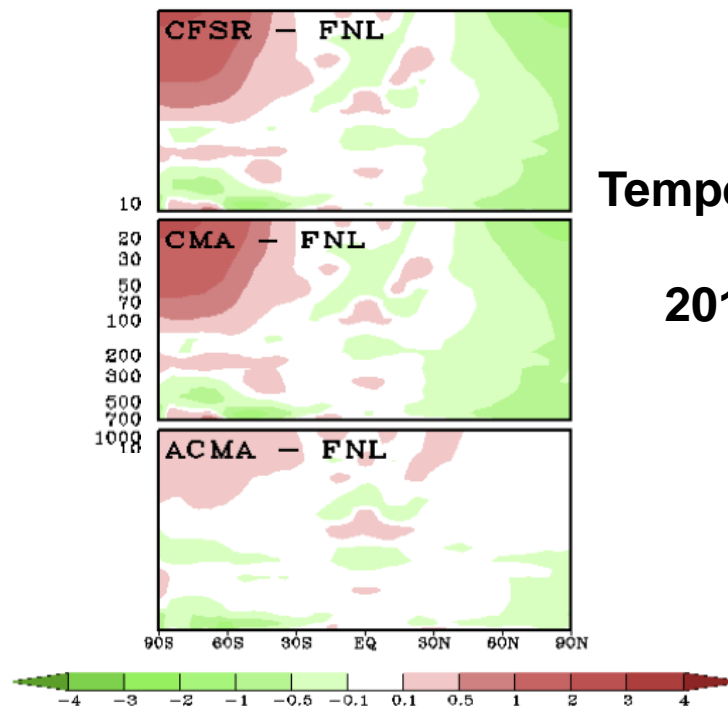


Now more challenging part: Assimilate NMIC-processed obs with GFS/GSI

- Since 2014, NMIC has collected >100TB raw observations
 - Conventional and satellite data
 - Intended to convert them to NCEP BUFR format for GSI assimilation
- In late 2015, we found NOAA released CFSR assimilated BUFR observations (1979-2014)
- New strategy: based on CFSR dataset,
 - Replace CFSR's upper air and surface data by NMIC data over China
 - Replace some satellite data with newly reprocessed version

GFS/GSI-3DVAR experiments running (from 2013.5)

	Conventional	Satellite data
CFSR	CFSR PREPBUFR	amsua + gpsro + satwnd
CMA	CFSR PREPBUFR + China Conventional obs	amsua + gpsro + satwnd
ACMA	CFSR PREPBUFR + China Conventional obs	More radiance + gpsro satwnd



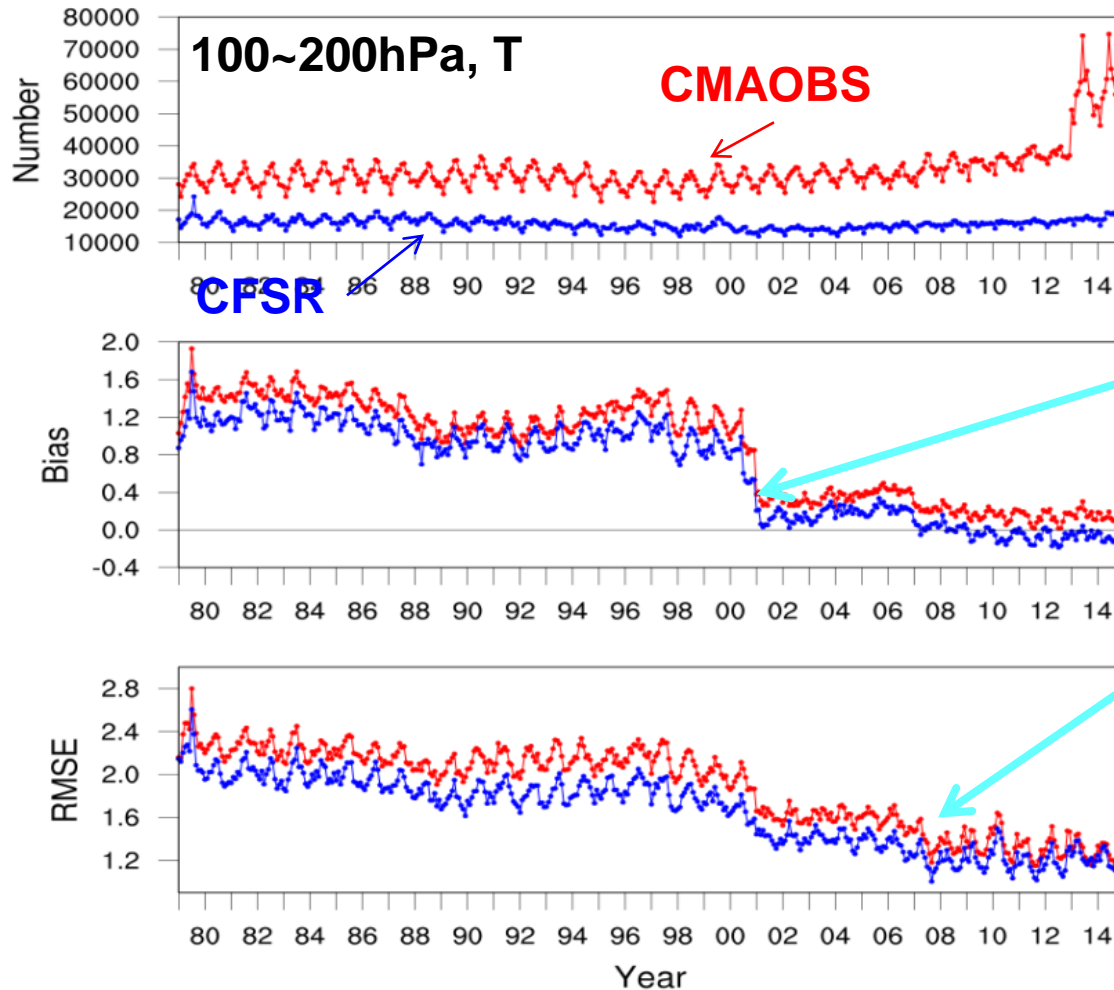
Temperature analysis minus FNL

2013/06/01 – 2013/11/30



国家气象信息中心
National Meteorological Information Center

Challenges still remain in historical data processing/QC/bias correction



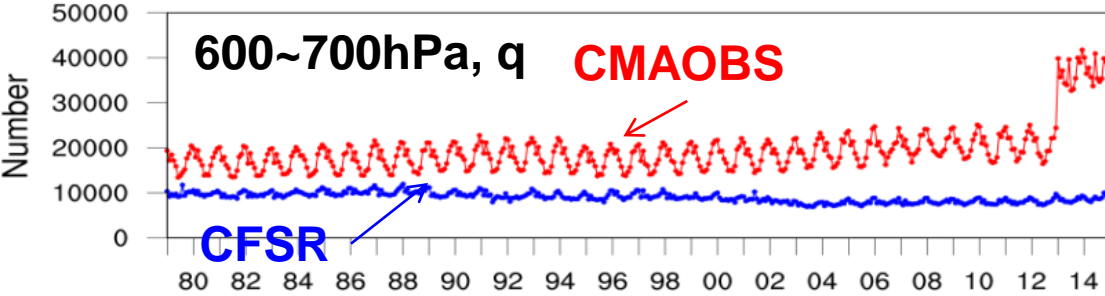
Large T bias in Chinese radiosondes prior to 2001, when data processing method updated

Smaller jump after changing radiosonde sensor in 2007

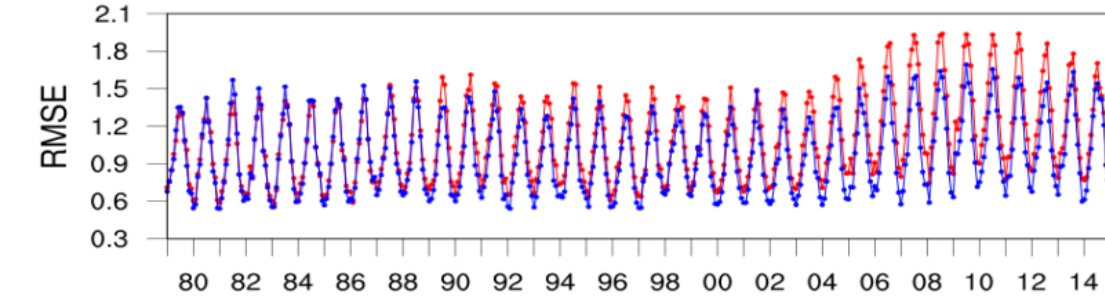
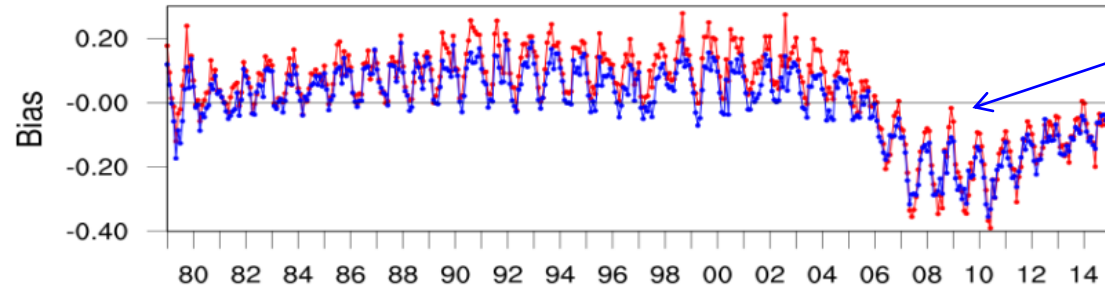
Monthly bias and RMSE (reference: ERA-Interim reanalysis)



国家气象信息中心
National Meteorological Information Center



dry bias after changing
radiosonde sensor in
2007



Monthly bias and RMSE (reference: ERA-Interim reanalysis)

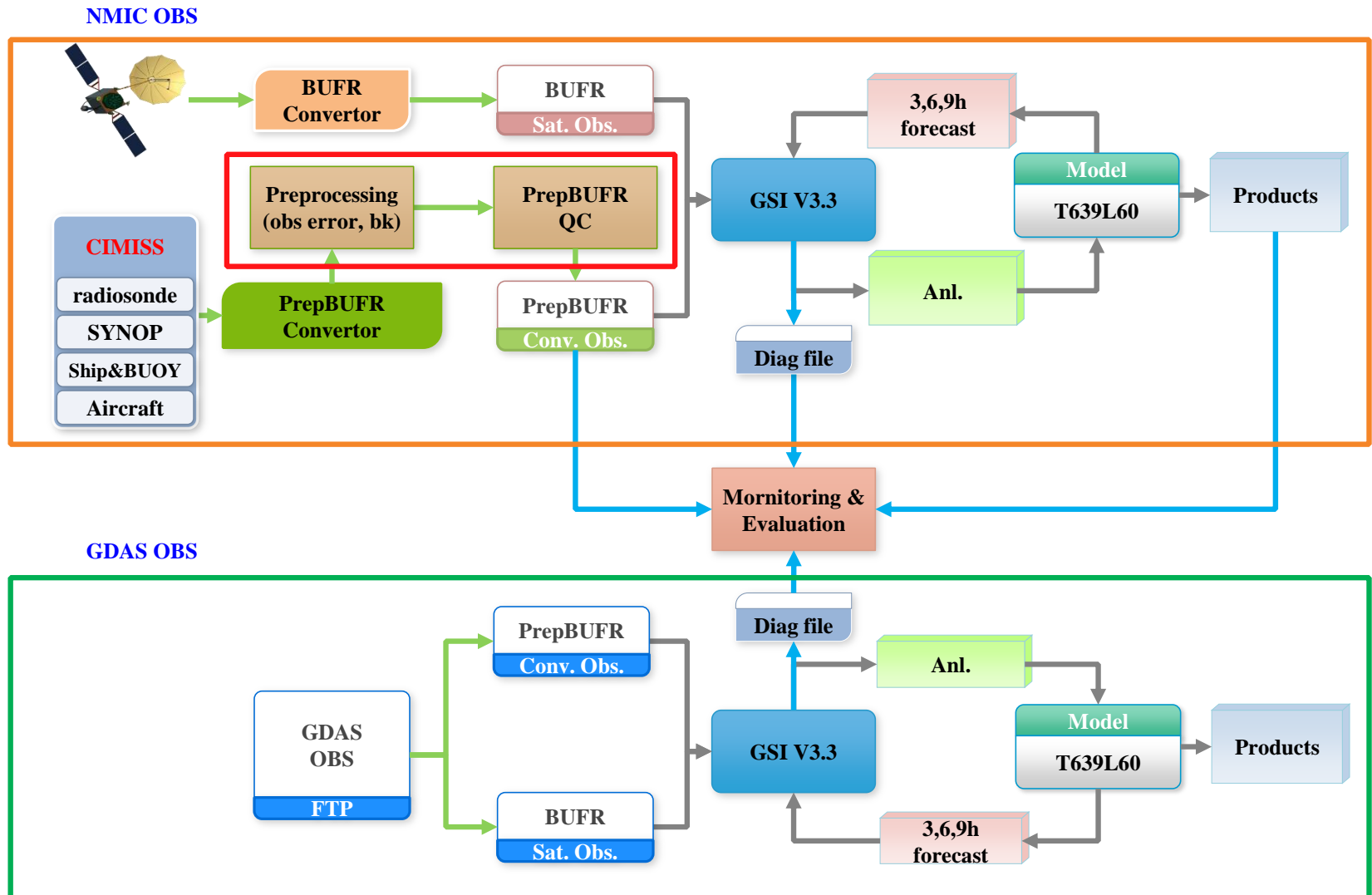
Outline

- Background
- **Progress in the past two more years**
 - T639/GSI based reanalysis experiments (2015)
 - GFS/GSI based reanalysis experiments (2016)
 - **Implementation of the NRT system (2016)**
- Future Plan

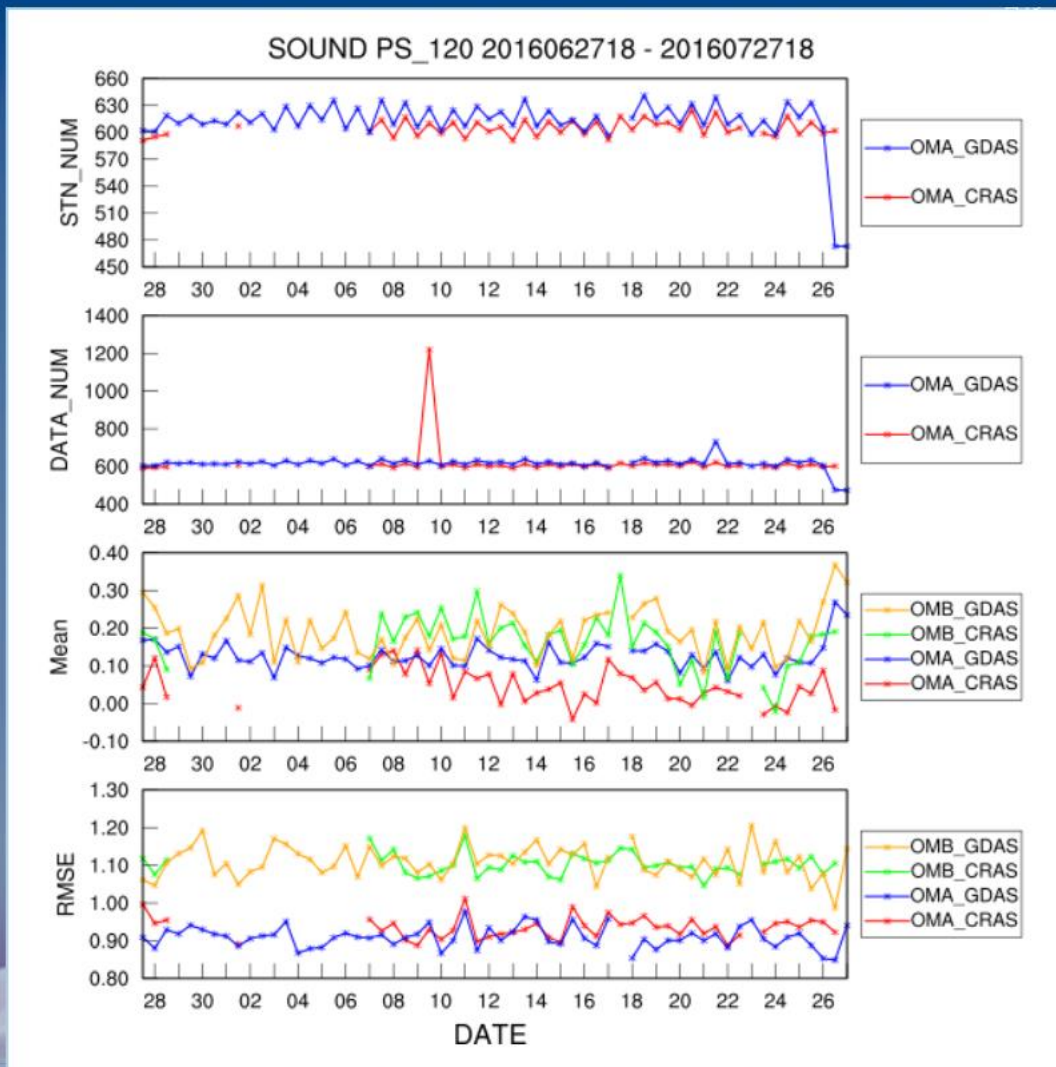


Implementation of NRT running system

- To solve RT observation issues in NMIC
- Two sub-systems running in parallel: T639+GDAS OBS; T639+NMIC OBS



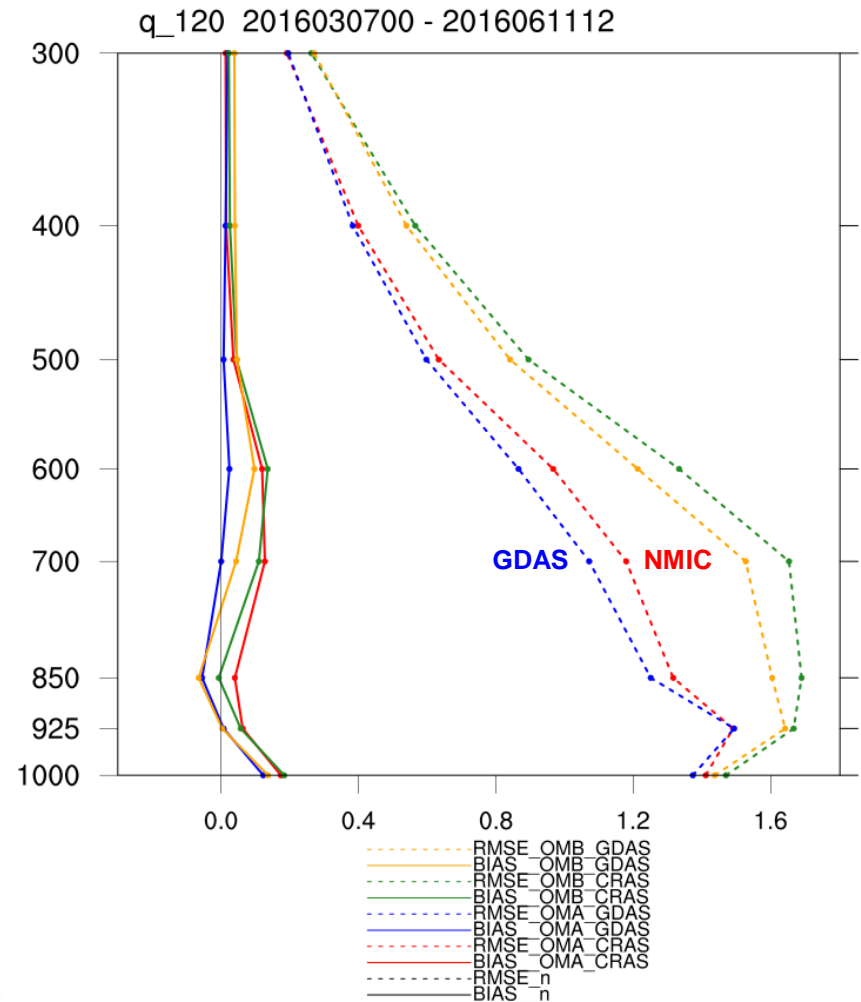
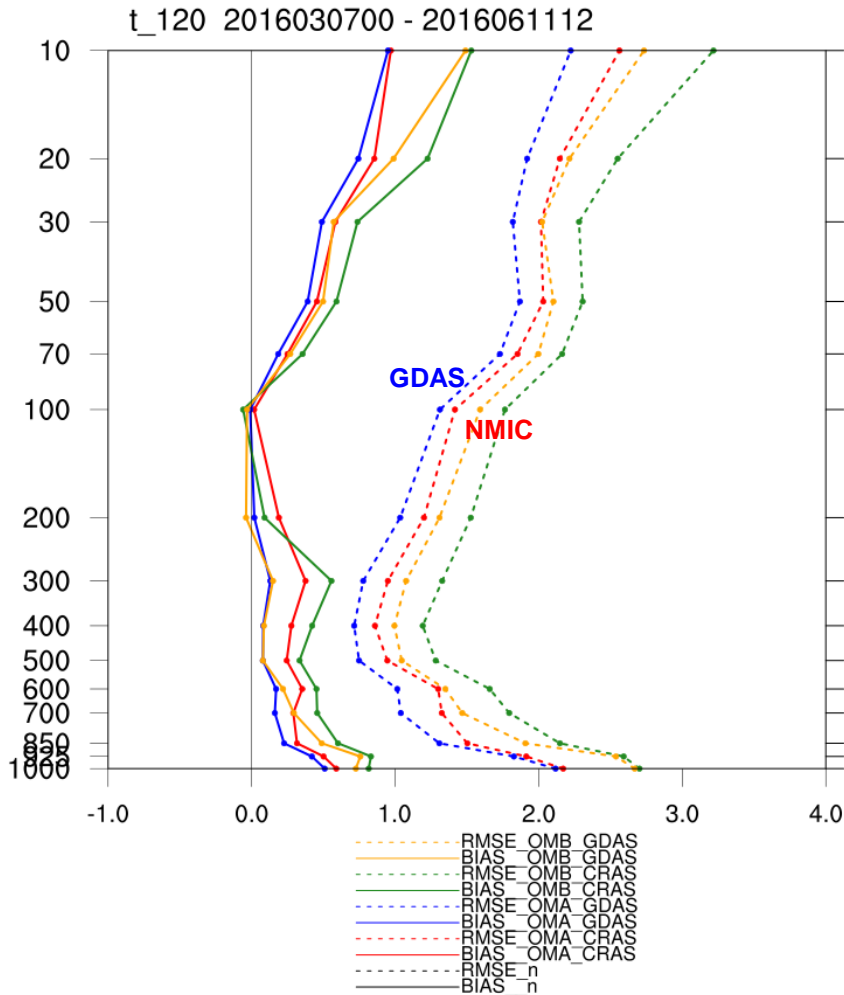
Monitoring of the NRT running system



TOTAL	全球
1000	中国
925	北半球
850	南半球
700	高纬度
600	热带
500	
400	
300	
200	
100	
70	
50	
30	
20	
10	
0	

Issues in NRT running system

- NMIC-processed real-time obs feed has larger bias and RMSE than GDAS based obs.



2017 Plan

- Fully move to GFS/GSI system for at least historical experiments
- Then can focus more on observation aspects
- Plan to produce CRA-Interim product with 3DVAR for longer period (depending computing resource and progress on observation side)

Project Timeline

