Applications of FengYun satellite data in climate monitoring

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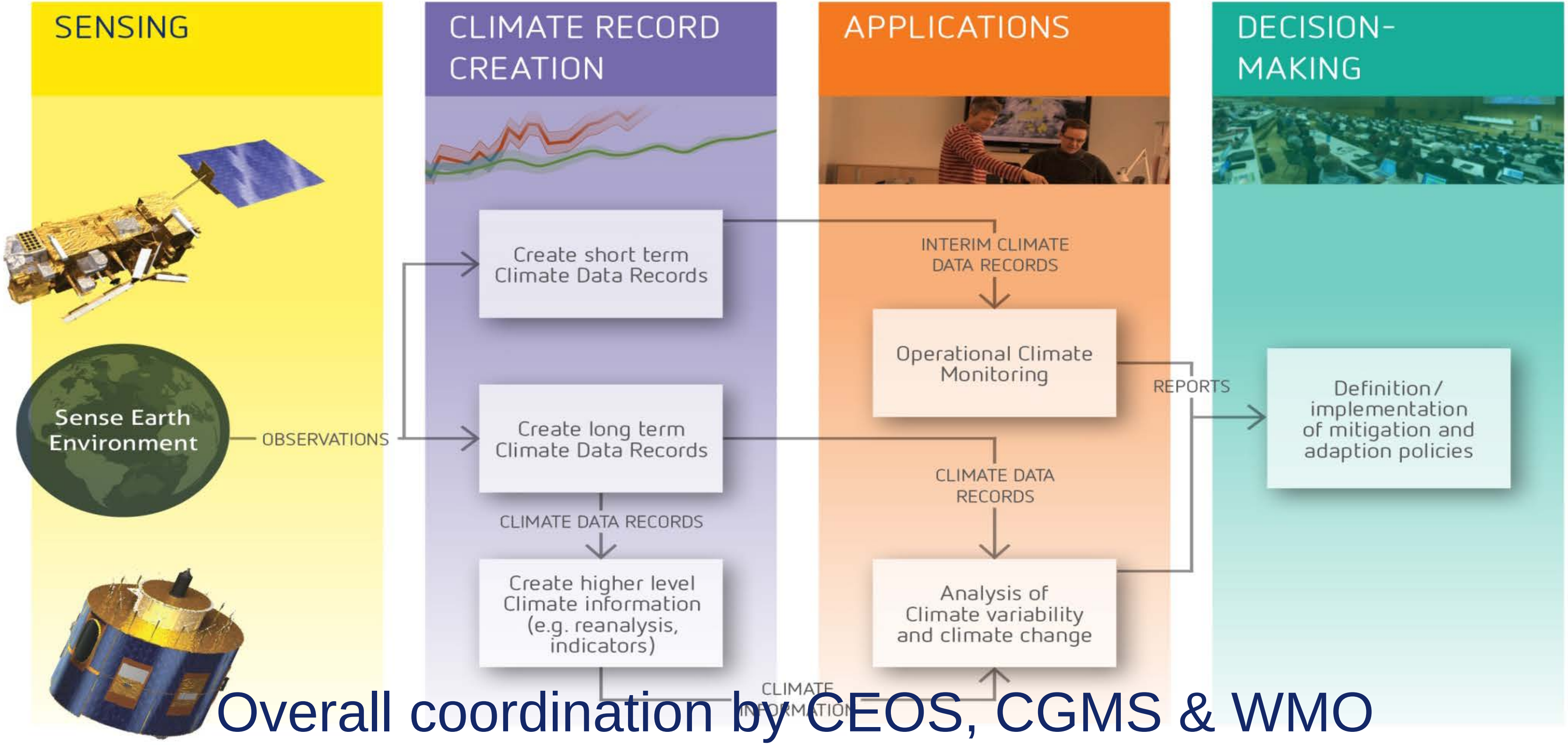
National Satellite Meteorological Center, CMA

Thanks to all contributors

Implementation of Climate Monitoring from space



SENSING

Sense Earth Environment

OBSERVATIONS

CLIMATE RECORD CREATION

Create short term Climate Data Records

Create long term Climate Data Records

CLIMATE DATA RECORDS

Create higher level Climate information (e.g. reanalysis, indicators)

CLIMATE INFORMATION

APPLICATIONS

INTERIM CLIMATE DATA RECORDS

Operational Climate Monitoring

CLIMATE DATA RECORDS

Analysis of Climate variability and climate change

DECISION-MAKING

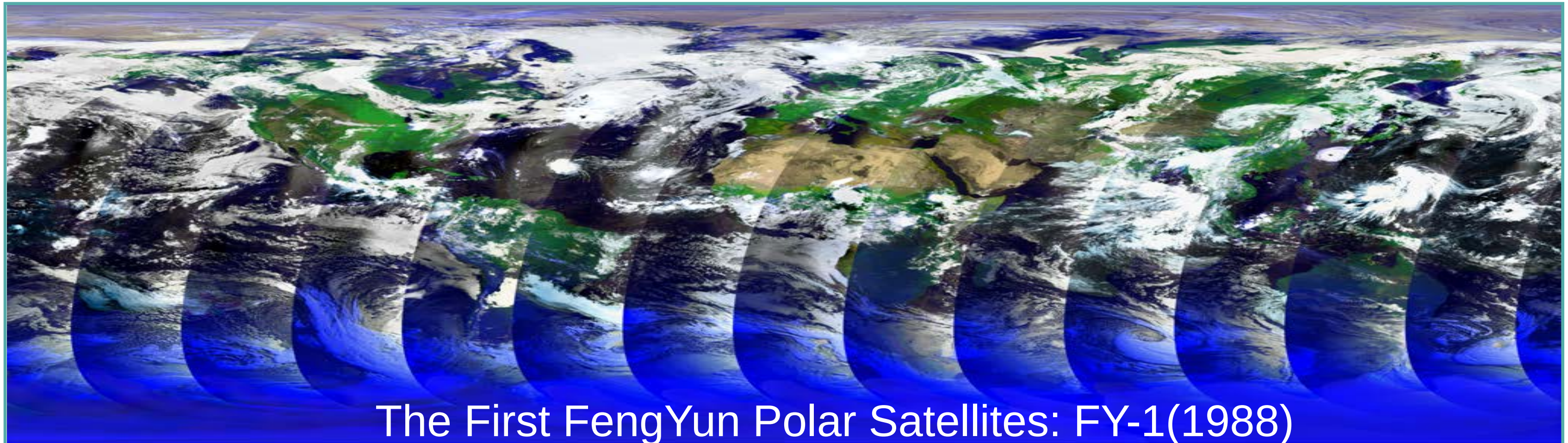
REPORTS

Definition / implementation of mitigation and adaption policies

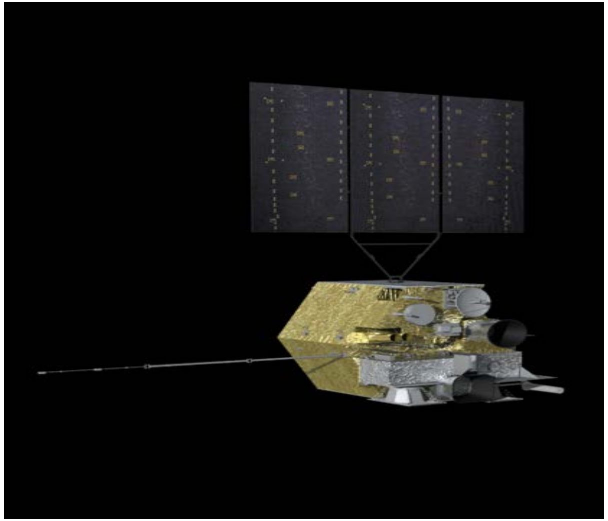
Overall coordination by CEOS, CGMS & WMO

30 years: From EXPERIMENT to OPERATION

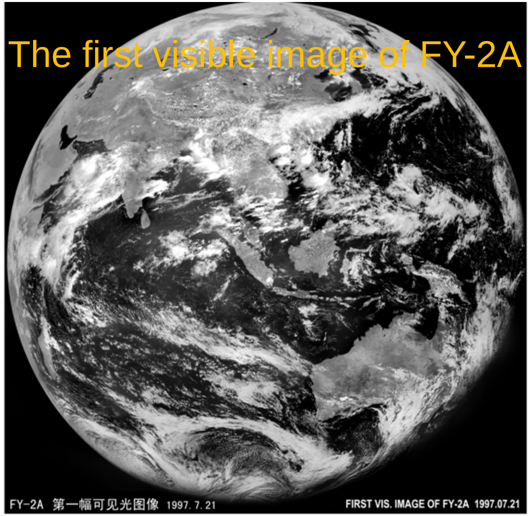
No.	Satellite_ID	Launched time	End of service
1	**FY-1A**	1988.09	1988.10
2	**FY-1B**	1990.09	1991.08
3	**FY-1C**	1999.05	2004.04
4	**FY-1D**	2002.05	2012.04
5	**FY-3A**	2008.05	2015.01
6	**FY-3B**	2010.11	
7	**FY-3C**	2013.9	
8	**FY-3D**	2017.11	



The First FengYun Polar Satellites: FY-1(1988)

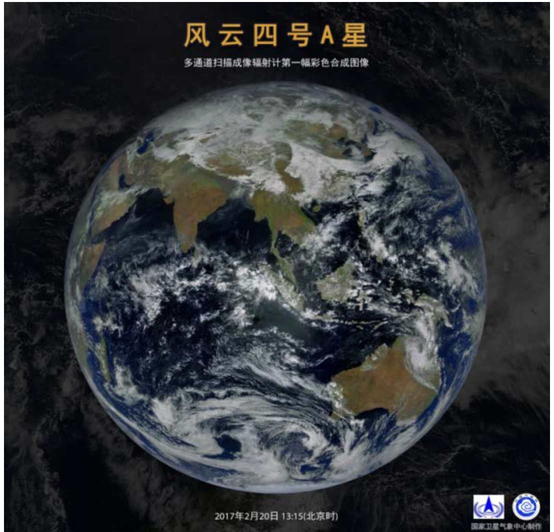


No	Satellite-ID	Coverage	Launch time	End of service
1	FY-2A	Full Disk / 1-h	1997.06	1998.04
2	FY-2B	Full Disk /1-h	2000.06	2004.09
3	FY-2C	Full Disk /1-h	2004.10	2009.11
4	FY-2D	Full Disk /1-h	2006.11	2015.06
5	FY-2E	Full Disk /1-h	2008.12	
6	FY-2F	Full Disk / 1-h + Regional Rapid Scan / <6 min	2012.01	
7	FY-2G	Full Disk /1-h	2014.12	
8	FY-2H	Full Disk /1-h	2018.06	
9	FY-4A	Full Disk /15-min	2016.12	

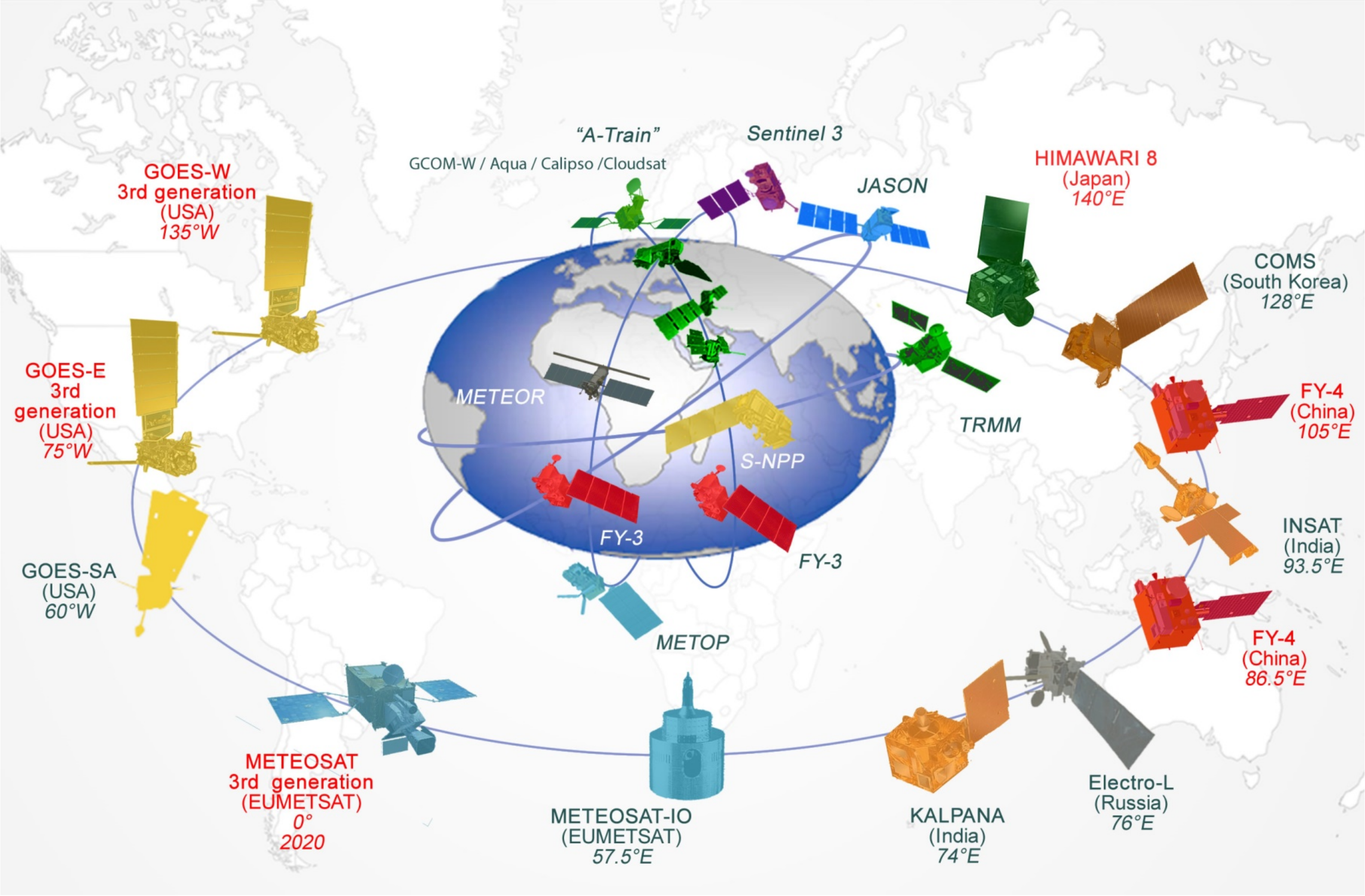


The first visible image of FY-2A

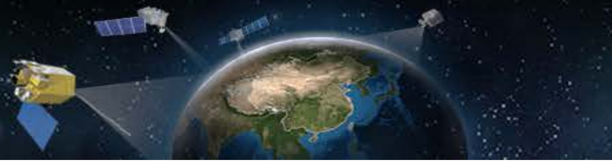
FY-2A 第一幅可见光图像 1997. 7. 21
FIRST VIS. IMAGE OF FY-2A 1997.07.21



风云四号A星
多通道扫描成像辐射计第一幅彩色合成图像
2017年2月20日 13:15(北京时)
国家卫星气象中心制作

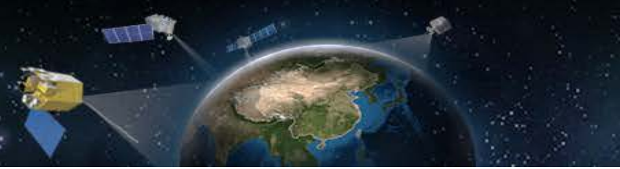

"A-Train"
GCOM-W / Aqua / Calipso /Cloudsat
Sentinel 3
JASON
HIMAWARI 8
(Japan)
140°E
GOES-W
3rd generation
(USA)
135°W
COMS
(South Korea)
128°E
GOES-E
3rd
generation
(USA)
75°W
METEOR
FY-4
(China)
105°E
TRMM
S-NPP
FY-3
FY-3
INSAT
(India)
93.5°E
GOES-SA
(USA)
60°W
METOP
FY-4
(China)
86.5°E
METEOSAT
3rd generation
(EUMETSAT)
0°
2020
METEOSAT-IO
(EUMETSAT)
57.5°E
KALPANA
(India)
74°E
Electro-L
(Russia)
76°E

FY-3 products



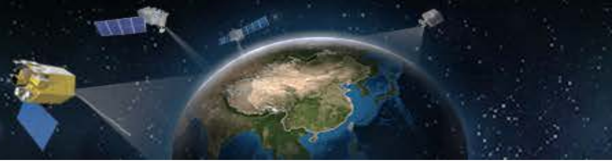
	Products of FY-3A/3B/3C	New products of FY-3D
Atmospheric	Cloud mask, fog detection, Cloud Amount,cloud type, cloud phase, cloud top temperature/height, cloud optical depth, Profile,cloud water content， Cloud Liquid Water, outgoing longwave radiation，Flux at TOA , atmospheric Total Precipitable Water , Dust Storm Index, aerosol optical depth, rain detection, Atmospheric Humidity/temperature, precipitation, Total Ozone, Ozone Profile,Ice Water Paths, Microwave Rain Rate and Aerosol index, GNOS atmospheric density profile, GNOS atmospheric temperature profile, GNOS refractivity profile, GNOS atmospheric humidity profile， atmospheric motion vector	CO2 、 CO 、 CH4 、 O2
Land	Global Fire detection, Land Cover, Land Surface reflectance, Land Surface Temperature, soil moisture, albedo, NDVI, LAI, FPAR, NPP, Snow Cover, snow depth/Snow Water Equivalent	
Ocean	SST，Sea-Ice coverage, Ocean Color/Chlorophyll, Sea surface wind speed	

FY-2 and FY-4 Products



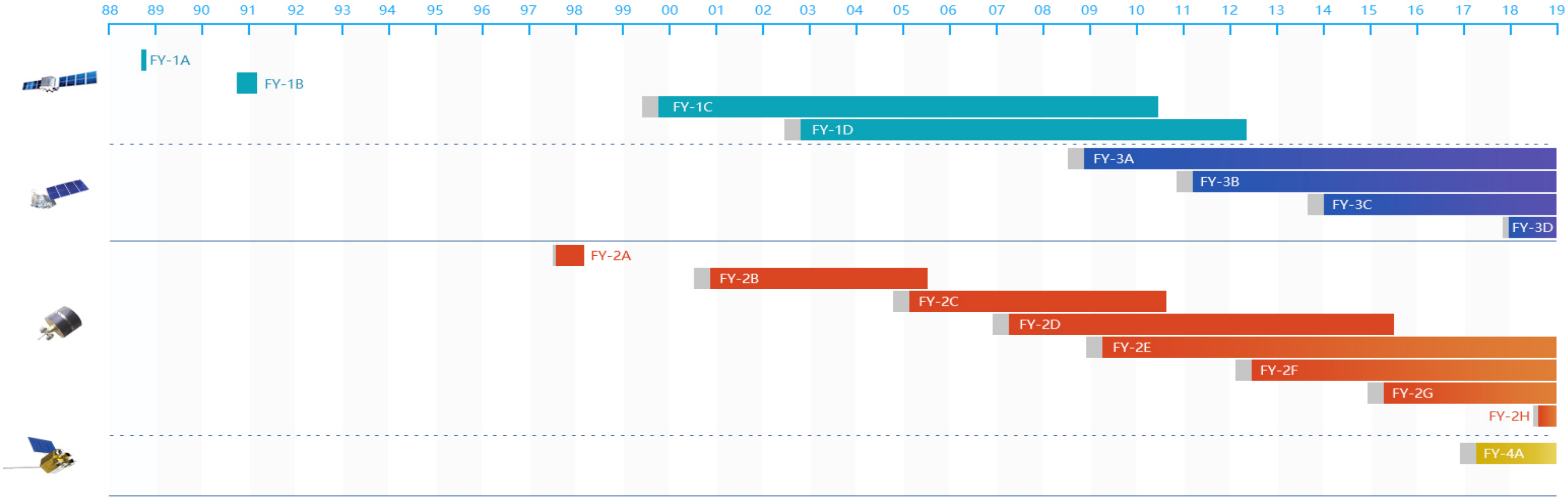
FY-2 C/D/E operational products	FY-2 F/G/H operational products	FY-4A baseline products
Upper Tropospheric Humidity	Upper Tropospheric Humidity	
Precipitation Estimation	Precipitation Estimation	Rainfall Rate/QPE
	Atmospheric Motion Vector	Atmospheric Motion Vector
		Lightning Detection
Surface Solar Irradiance	Surface Solar Irradiance	Surface Solar Irradiance
Blackbody brightness temperature	Blackbody brightness temperature	Blackbody brightness temperature
Outgoing Long wave Radiation	Outgoing Long wave Radiation	Outgoing Long wave Radiation
		Downward Long wave Radiation: Surface
		Upward Long wave Radiation: Surface
		Reflected Shortwave Radiation: TOA
	Land Surface Temperature	Land Surface (Skin) Temperature
Sea Surface Temperature	Sea Surface Temperature	Sea Surface Temperature (skin)
		Land Surface Temperature
		Land Surface Albedo
		Land Surface Emissivity
Snow Cover	Snow Cover	Snow Cover
		Fire/Hot Spot Characterization

FY-2 and FY-4 Products



FY-2 C/D/E operational products	FY-2 F/G/H operational products	FY-4A baseline products
Cloud Detection	Cloud Detection	Clear Sky Masks
Cloud Classification	Cloud Classification	Cloud Type
Total Cloud Amount	Total Cloud Amount	
		Cloud Optical Depth
		Cloud Liquid Water
		Cloud Particle Size Distribution
		Cloud Phase
	Cloud Top Temperature	Cloud Top Temperature
		Cloud Top Height/Pressure
		Fog Detection
Dust Detection	Dust Detection	Aerosol Detection
		Aerosol Optical Depth
Humidity product	Humidity product	
		Atmospheric temperature profile
		moisture profile
		ozone profile and total ozone amount
		atmosphere stability index
		Lightning Group and Event

FCDR for FengYun satellites



Sensor:

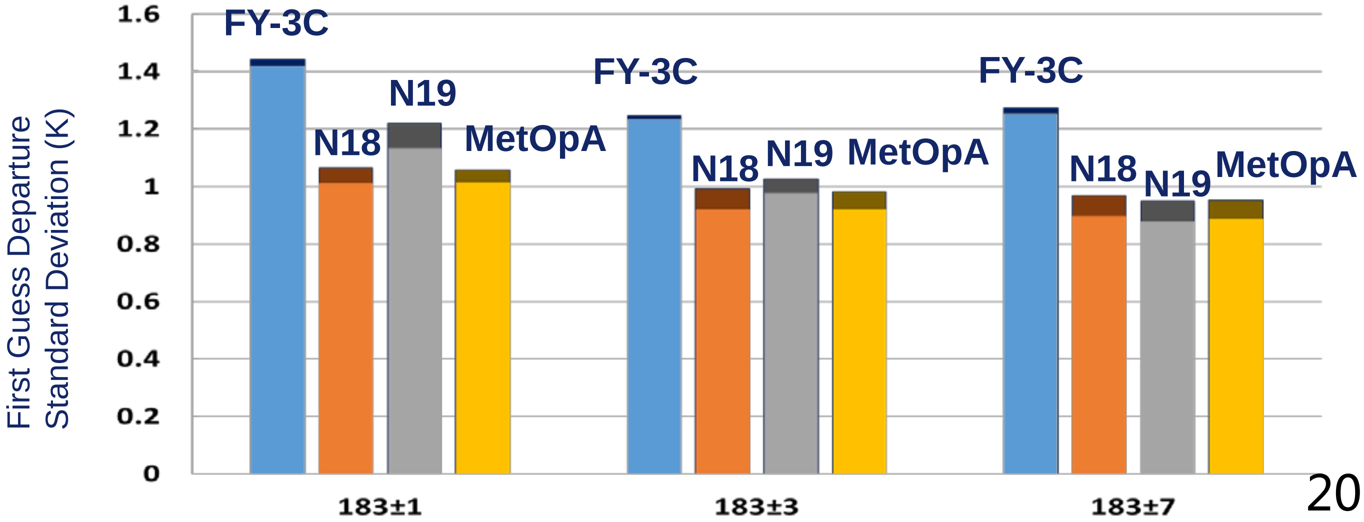
- FY-1A/B/C/D FY-3A/B/C VIRR
- FY-3A/B/C MERSI/IRAS/MWTS/MWHS/MWRI
- FY-2A/B/C/D/E/G VISSR

Accuracy:

- RSB: 8%(Exp.), 5%(Ope.)
- TIR: 1K(Exp.), 0.5K(Ope.)
- MW: 1K(Absorb),1.5K(Window)

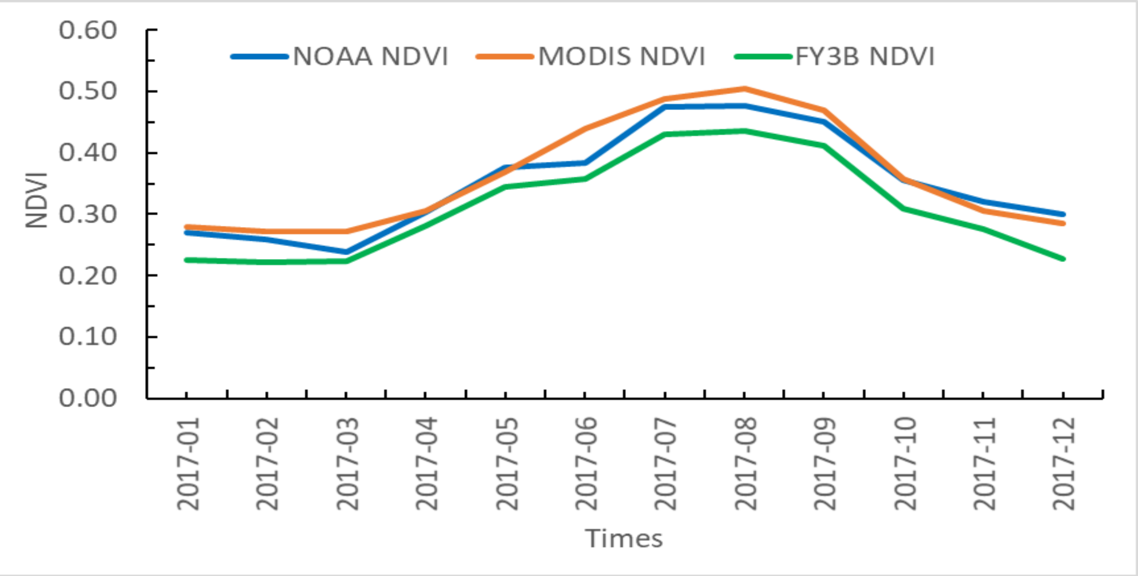
FY-3C MWHTS（ERA-Interim as background）

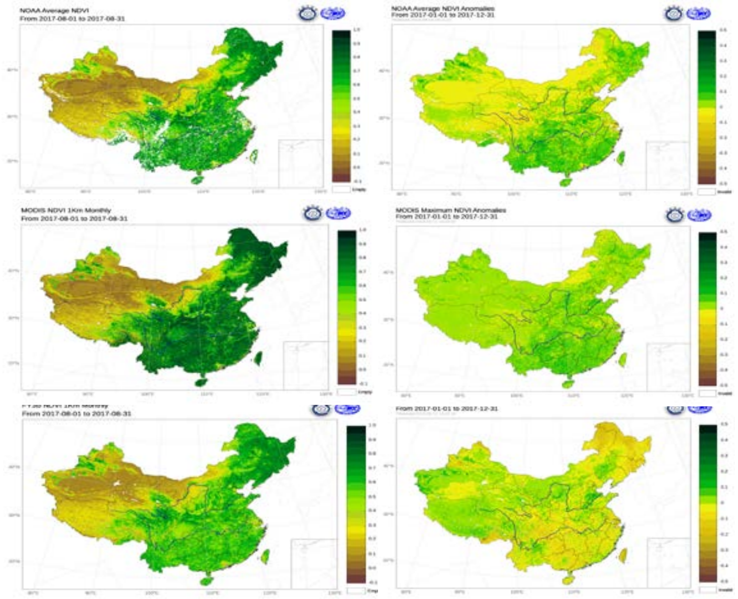
Central Freq.(GHz)	MWHTS	MHS	主要用途
183.31±1	**CH11**	**CH3**	**450hPa Humidity**
183.31±1.8	CH12	/	500hPa humidity
183.31±3	**CH13**	**CH4**	**600hPa humidity**
183.31±4.5	CH14	/	700hPa humidity
183.31±7	**CH15**	**CH5/190.311**	**800hPa humidity**



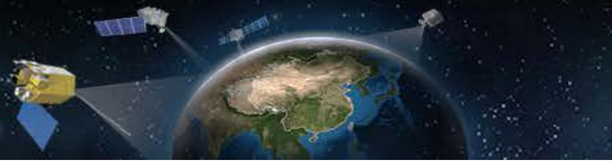
201401-201406

NDVI

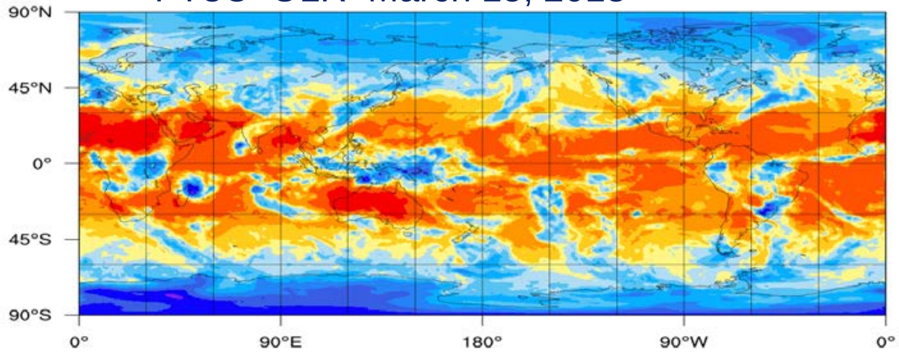

NOAA NDVI
MODIS NDVI
FY3B NDVI
NDVI
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2017-01
2017-02
2017-03
2017-04
2017-05
2017-06
2017-07
2017-08
2017-09
2017-10
2017-11
2017-12
Times


NOAA Average NDVI
From 2017-08-01 to 2017-08-31
NOAA Average NDVI Anomalies
From 2017-01-01 to 2017-12-31
MODIS NDVI 1Km Monthly
From 2017-08-01 to 2017-08-31
MODIS Maximum NDVI Anomalies
From 2017-01-01 to 2017-12-31
From 2017-08-01 to 2017-08-31
From 2017-01-01 to 2017-12-31

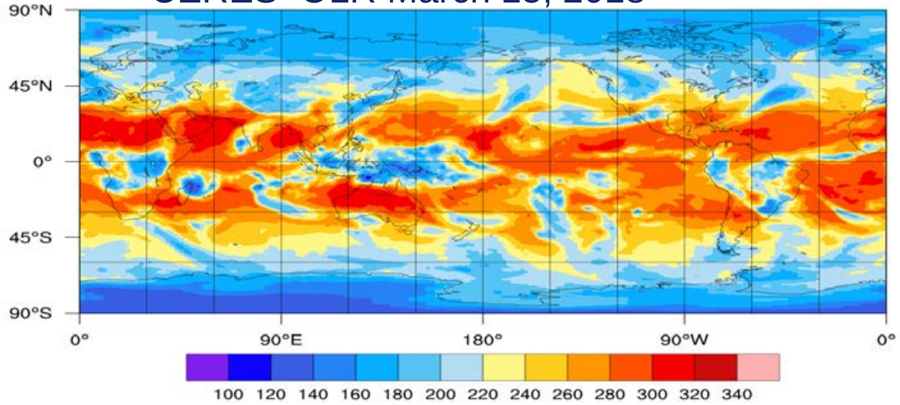
OLR (FY-3C & CERES)



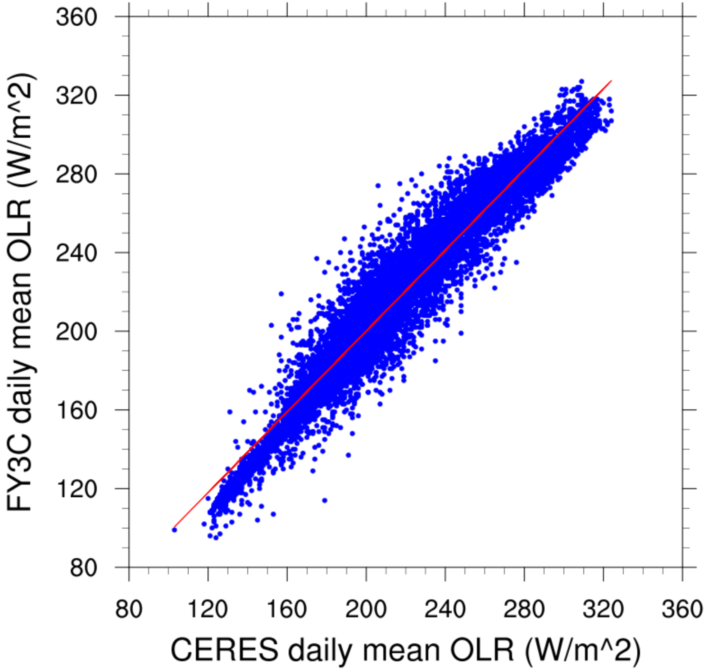
FY3C OLR March 15, 2018


90°N
45°N
0°
45°S
90°S
0°
90°E
180°
90°W
0°

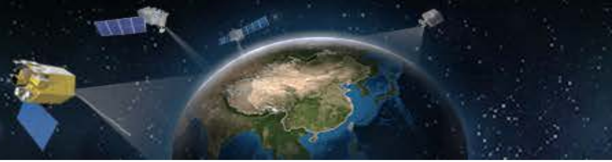
CERES OLR March 15, 2018

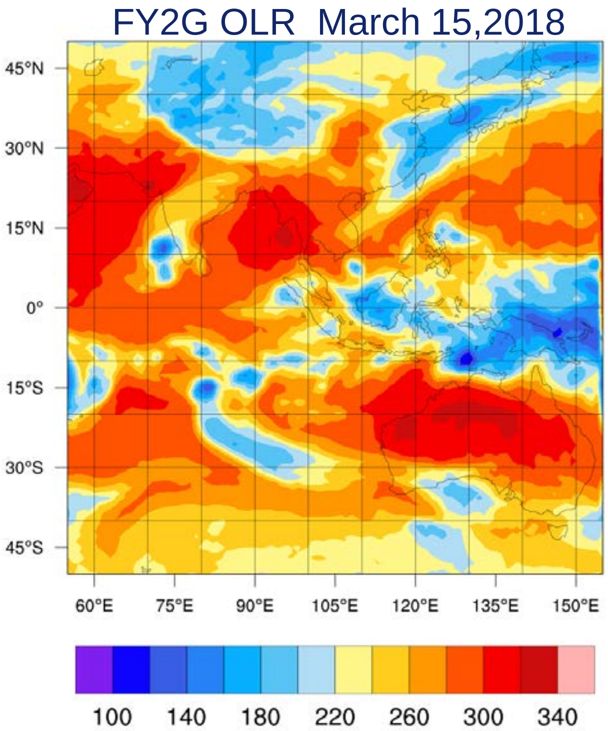

90°N
45°N
0°
45°S
90°S
0°
90°E
180°
90°W
0°
100 120 140 160 180 200 220 240 260 280 300 320 340

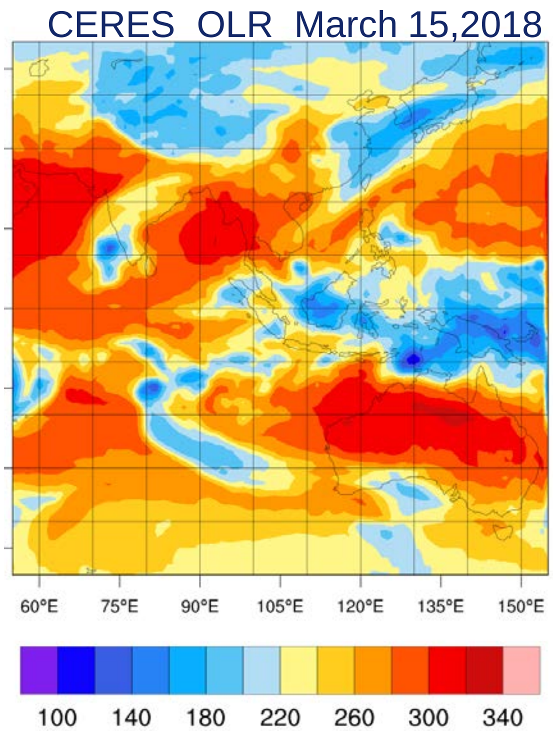
Scatter plot of FY3C and CERES daliy mean OLR
RMS=11.40 W/m^2 R=0.97 Bias=0.62 W/m^2

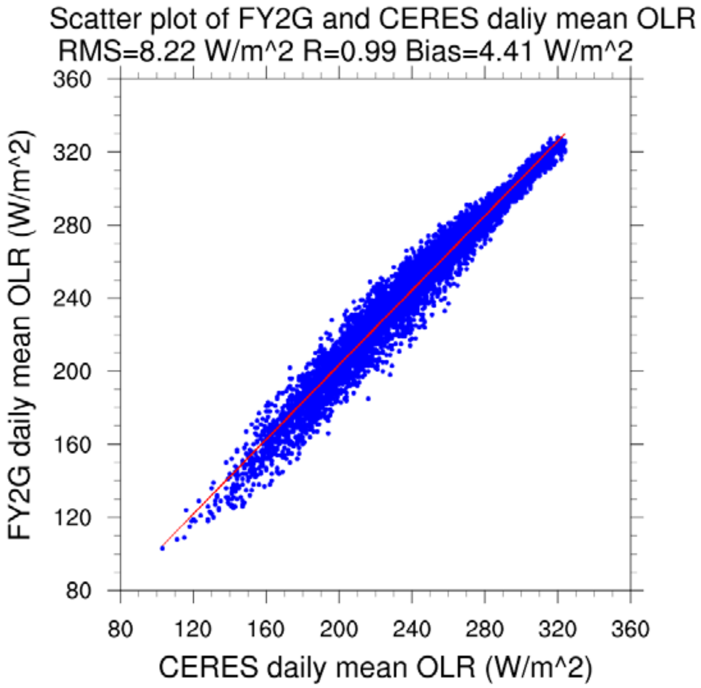


OLR (FY-2G & CERES)

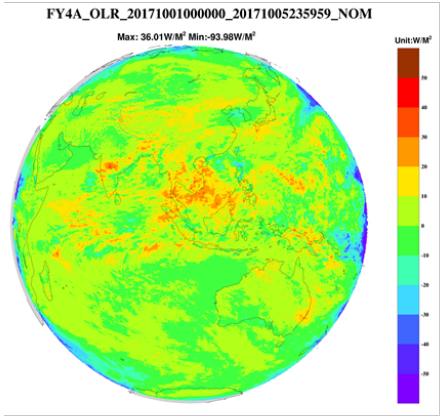



FY2G OLR March 15,2018
45°N
30°N
15°N
0°
15°S
30°S
45°S
60°E
75°E
90°E
105°E
120°E
135°E
150°E
100
140
180
220
260
300
340

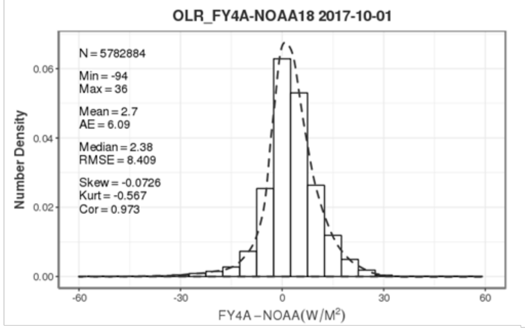

CERES OLR March 15,2018
60°E
75°E
90°E
105°E
120°E
135°E
150°E
100
140
180
220
260
300
340

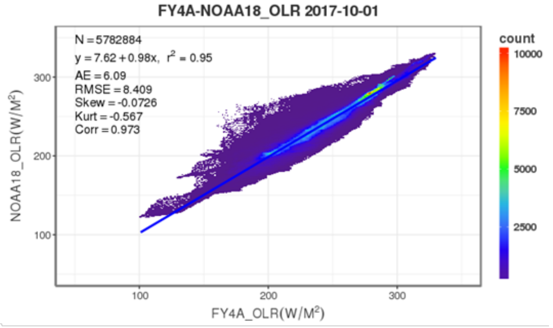

Scatter plot of FY2G and CERES daliy mean OLR
RMS=8.22 W/m^2 R=0.99 Bias=4.41 W/m^2

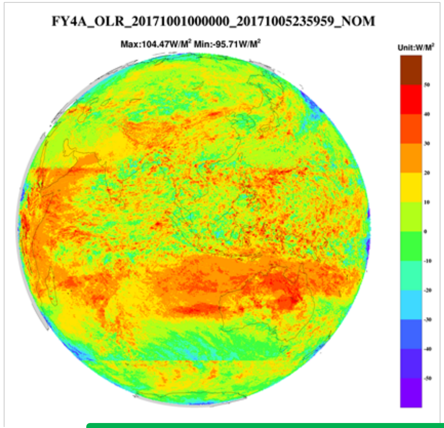
OLR


FY4A_OLR_20171001000000_20171005235959_NOM
Max: 36.01W/M² Min:-93.98W/M²
Unit:W/M²

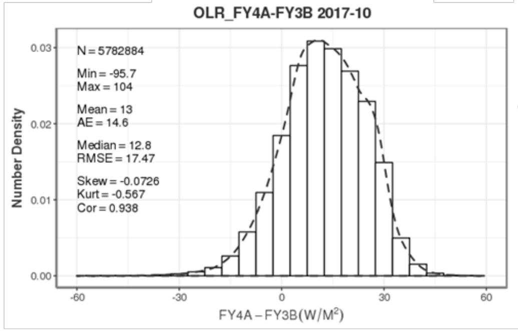
FY4 vs NOAA (HIRS)

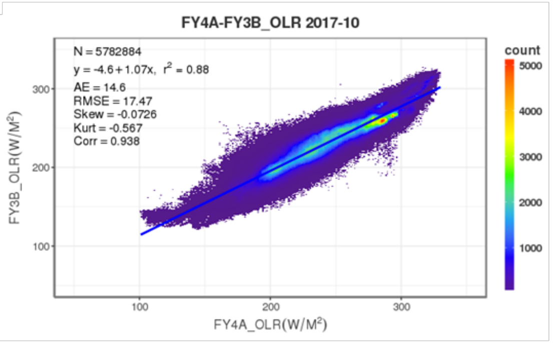





FY4A_OLR_20171001000000_20171005235959_NOM
Max:104.47W/M² Min:-95.71W/M²
Unit:W/M²

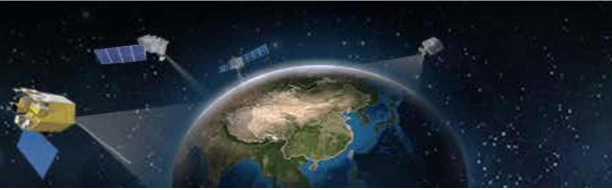
FY4 vs FY3B



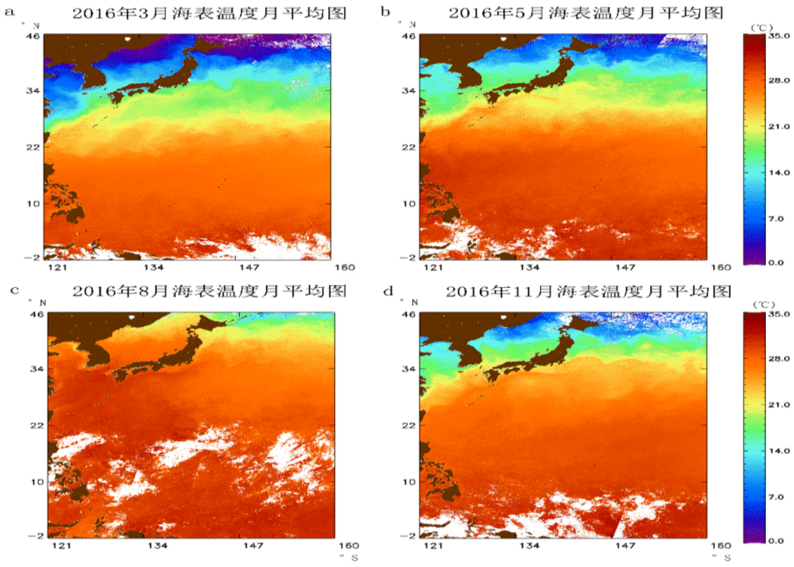


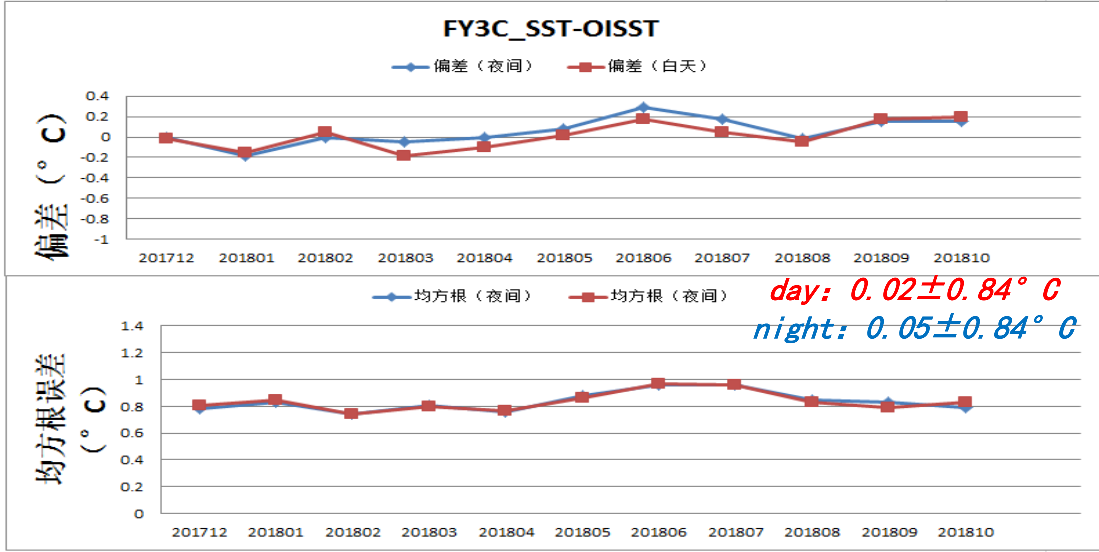
- FY4 OLR vs. HIRS (bias=2.7w/m², correlation=0.97) .
- FY3B (bias=13w/m², correlation=0.93).

FY-3C/VIRR SST



FY3C vs iQUAM	West Pacific area
High quality samples	-0.01±0.64K (D)
	0.16±0.58K (N)
all samples	- 0.12±0.79K (D)
	0.03±0.76K (N)

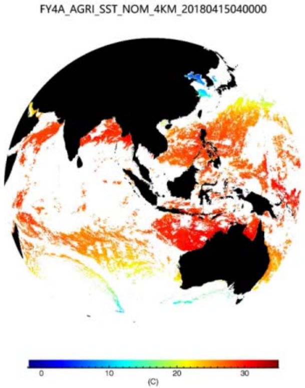

a
2016年3月海表温度月平均图
b
2016年5月海表温度月平均图
c
2016年8月海表温度月平均图
d
2016年11月海表温度月平均图
°N
46
34
22
10
−2
121
134
147
160
°S
(℃)
35.0
28.0
21.0
14.0
7.0
0.0

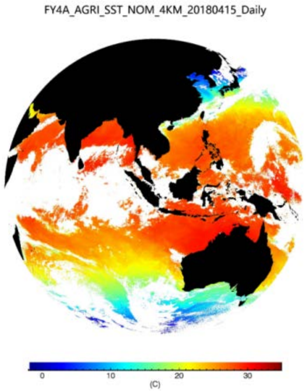


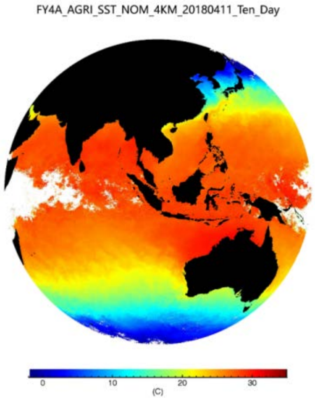
day: 0.02±0.84° C

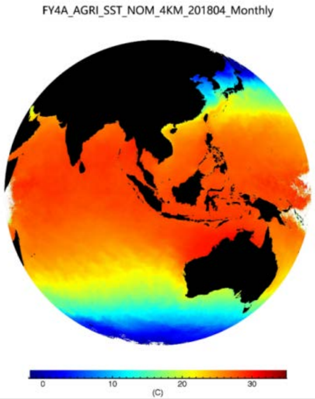
night: 0.05±0.84° C

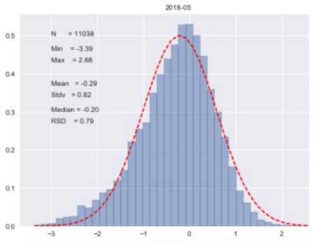
FY-4A/AGRI SST

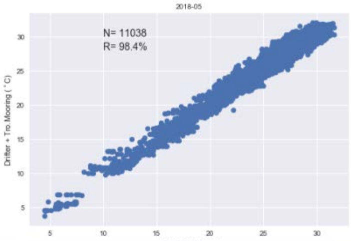

FY4A_AGRI_SST_NOM_4KM_20180415040000
0
10
20
30
(C)

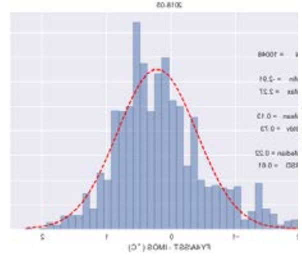

FY4A_AGRI_SST_NOM_4KM_20180415_Daily
0
10
20
30
(C)

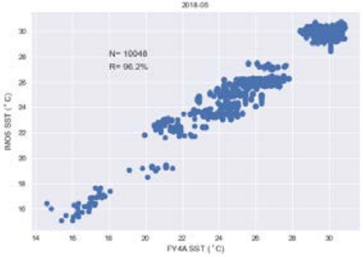

FY4A_AGRI_SST_NOM_4KM_20180411_Ten_Day
0
10
20
30
(C)

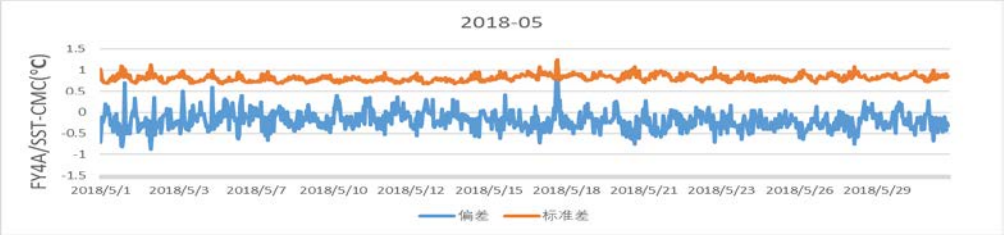

FY4A_AGRI_SST_NOM_4KM_201804_Monthly
0
10
20
30
(C)

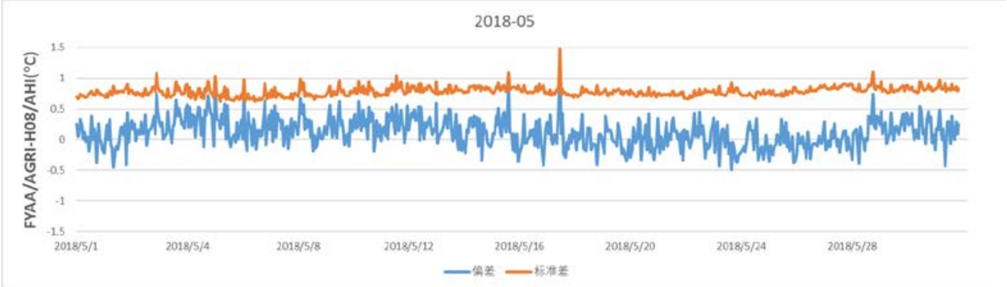






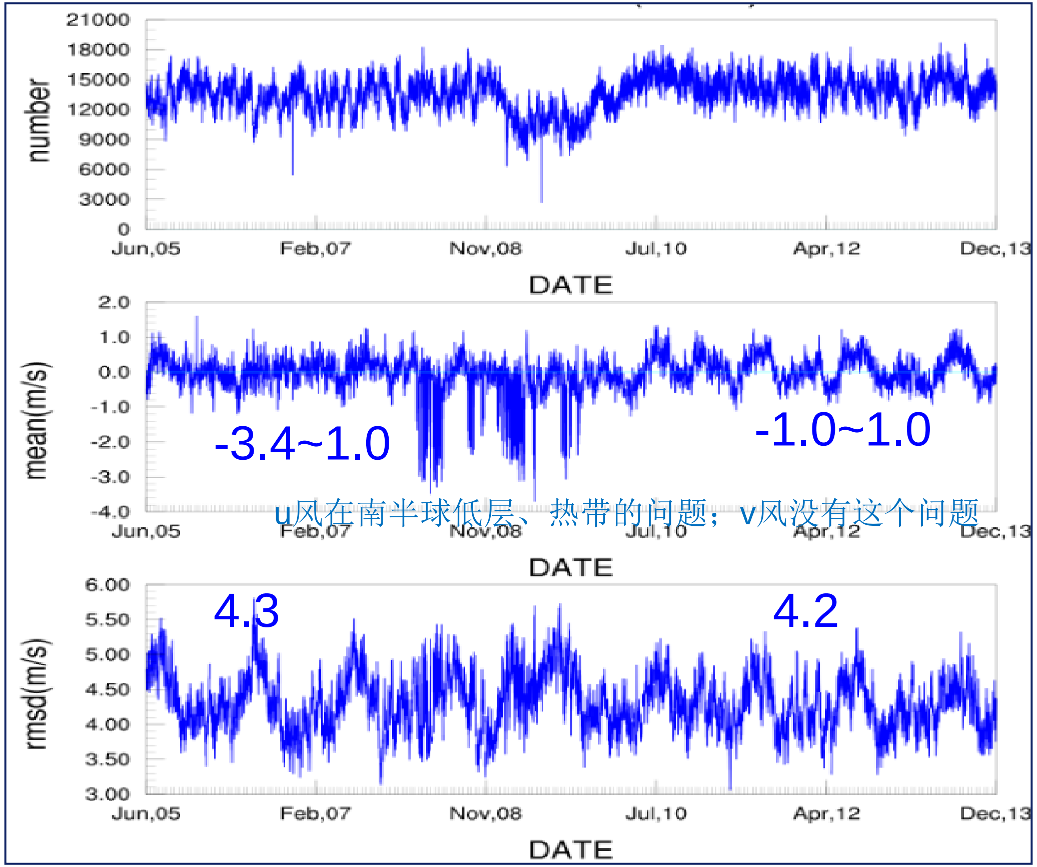






FY-2 AMV IR Pre-Assessment (ERA-Interim as background)

FY-2C/E AMV (IR, u)



-3.4~1.0

-1.0~1.0

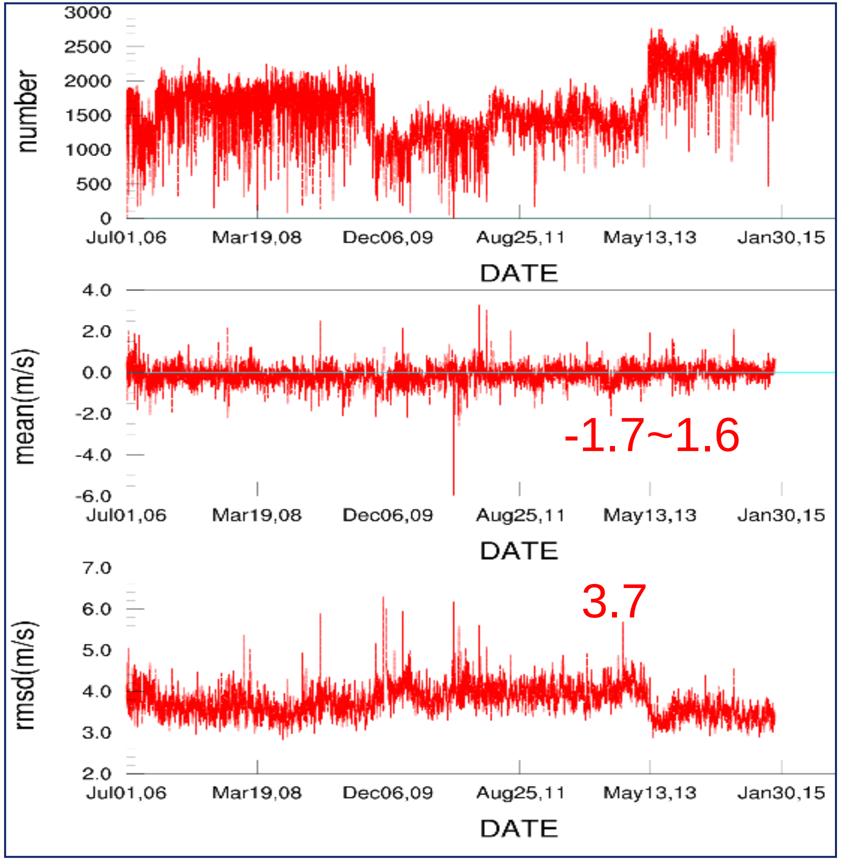
u风在南半球低层、热带的问题；v风没有这个问题

4.3

4.2

200506-201312

MTSAT-1R/2 AMV (IR, u)



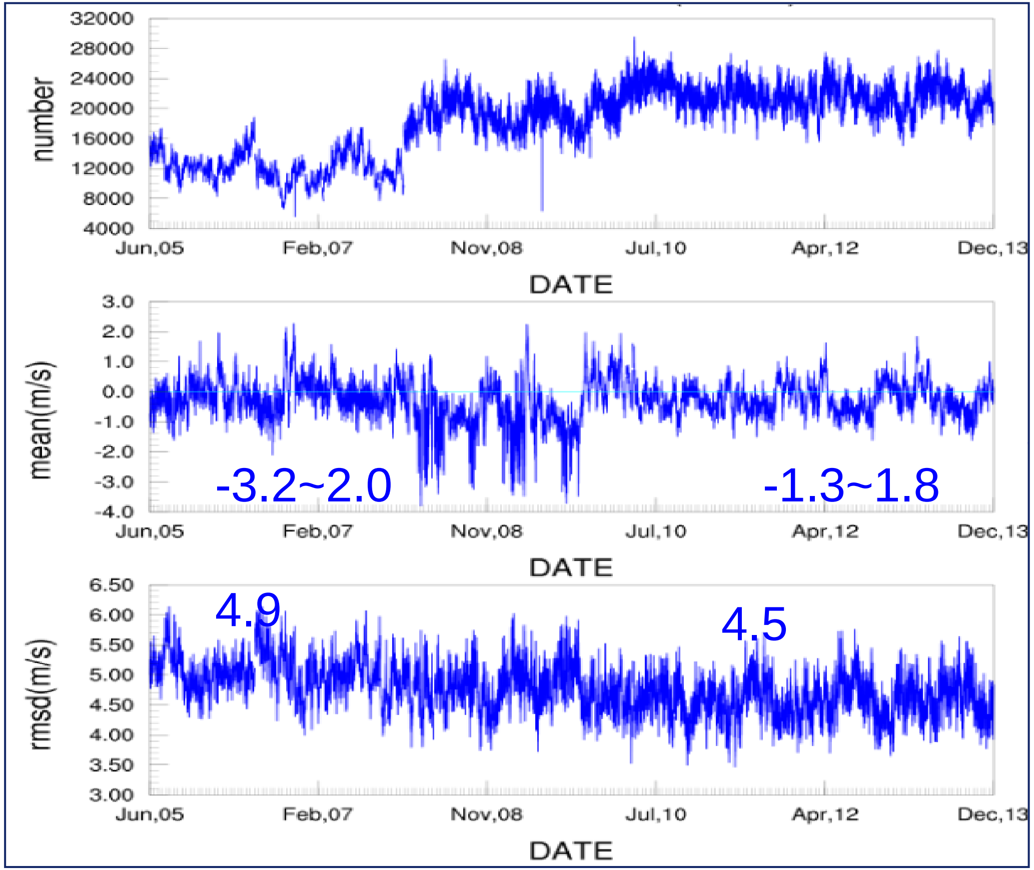
-1.7~1.6

3.7

200607-201412

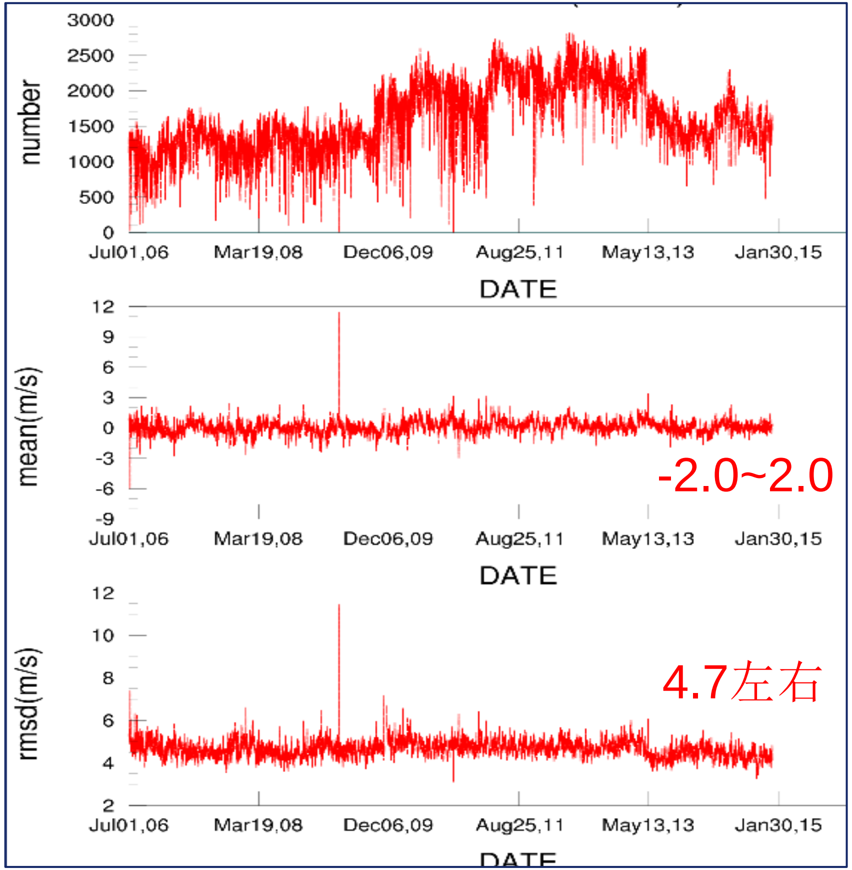
FY-2 AMV WV Pre-Assessment (ERA-Interim as background)

FY-2C/E AMV (WV, u)



200506-201312

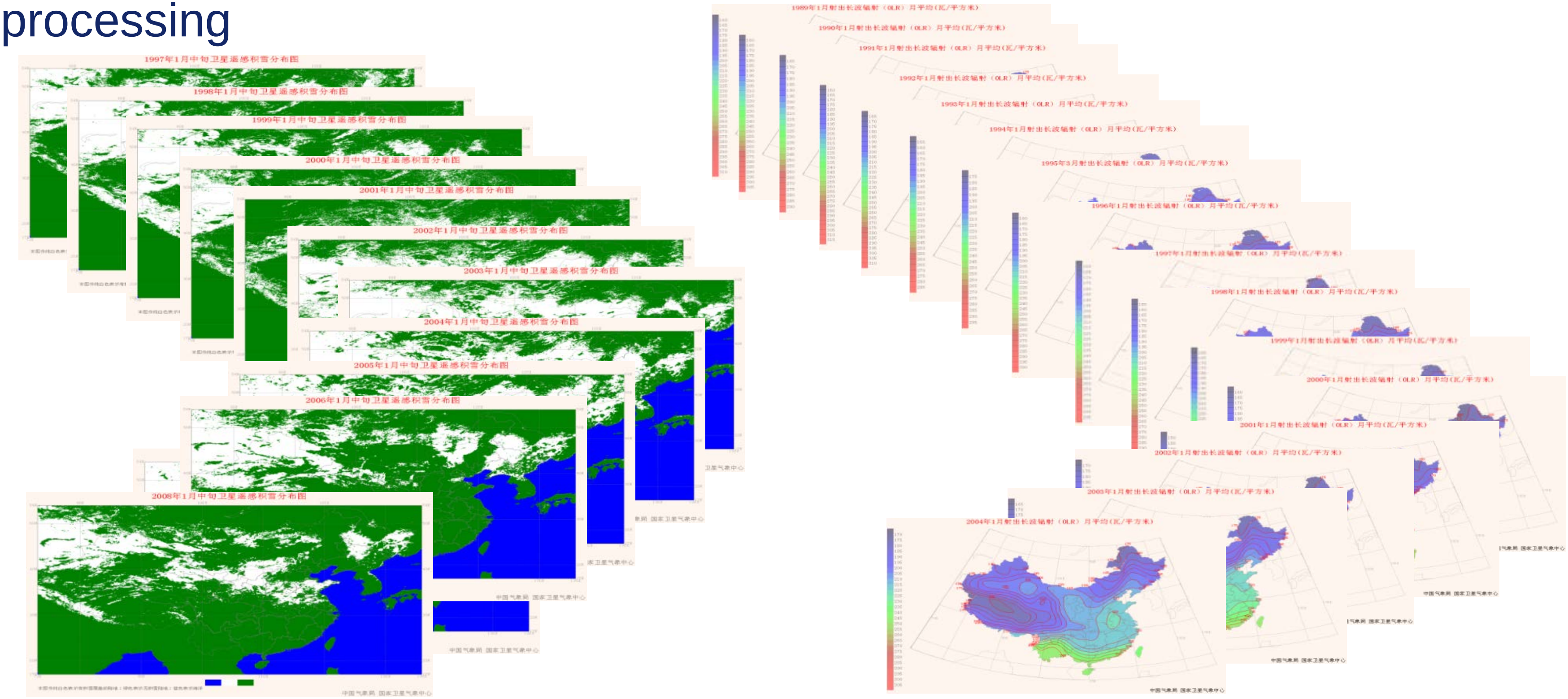
MTSAT-1R/2 AMV (WV , u)



200607-201412

Reprocessed long-term datasets

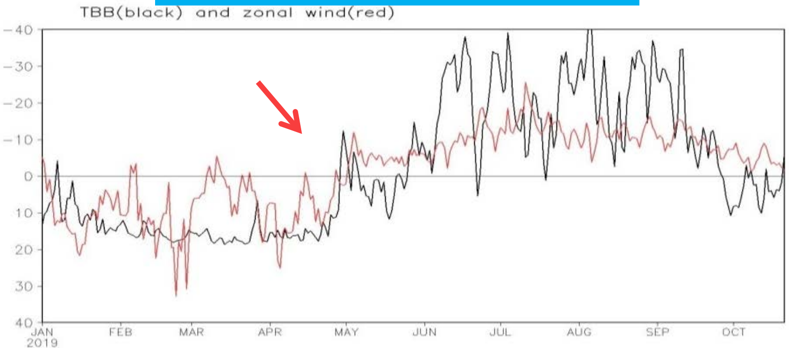
ECV variables such as Cloud, OLR, NDVI, LST, SST, Snow cover *et al*. are reprocessing


1997年1月中旬卫星遥感积雪分布图
1998年1月中旬卫星遥感积雪分布图
1999年1月中旬卫星遥感积雪分布图
2000年1月中旬卫星遥感积雪分布图
2001年1月中旬卫星遥感积雪分布图
2002年1月中旬卫星遥感积雪分布图
2003年1月中旬卫星遥感积雪分布图
2004年1月中旬卫星遥感积雪分布图
2005年1月中旬卫星遥感积雪分布图
2006年1月中旬卫星遥感积雪分布图
2008年1月中旬卫星遥感积雪分布图
中国气象局 国家卫星气象中心
1989年1月射出长波辐射（OLR）月平均(瓦/平方米)
1990年1月射出长波辐射（OLR）月平均(瓦/平方米)
1991年1月射出长波辐射（OLR）月平均(瓦/平方米)
1992年1月射出长波辐射（OLR）月平均(瓦/平方米)
1993年1月射出长波辐射（OLR）月平均(瓦/平方米)
1994年1月射出长波辐射（OLR）月平均(瓦/平方米)
1995年3月射出长波辐射（OLR）月平均(瓦/平方米)
1996年1月射出长波辐射（OLR）月平均(瓦/平方米)
1997年1月射出长波辐射（OLR）月平均(瓦/平方米)
1998年1月射出长波辐射（OLR）月平均(瓦/平方米)
1999年1月射出长波辐射（OLR）月平均(瓦/平方米)
2000年1月射出长波辐射（OLR）月平均(瓦/平方米)
2001年1月射出长波辐射（OLR）月平均(瓦/平方米)
2002年1月射出长波辐射（OLR）月平均(瓦/平方米)
2003年1月射出长波辐射（OLR）月平均(瓦/平方米)
2004年1月射出长波辐射（OLR）月平均(瓦/平方米)
中国气象局 国家卫星气象中心

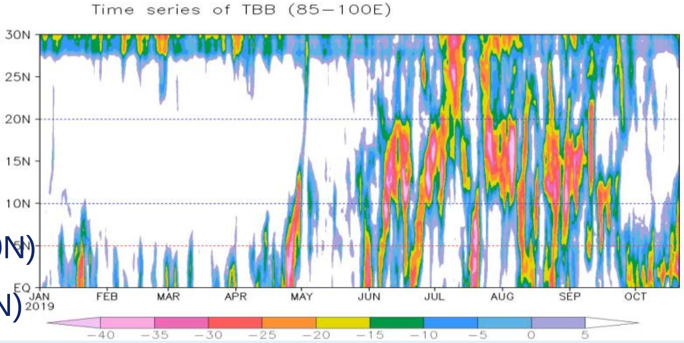
FY-2 products (AMV、 TBB) and FY3B products (OLR) is used in South China Sea(SCS) summer monsoon monitoring. AMV summer monsoon index：the wind field transition in SCS summer monsoon region.TBB summer monsoon convection index：the convection activity in SCS summer monsoon region.

Asia is the main active region of the monsoon. The onset time and intensity of summer monsoon significantly affect the distribution and intensity of rain belts and typhoon activities in the Asian monsoon.

BOB summer monsoon index in 2019



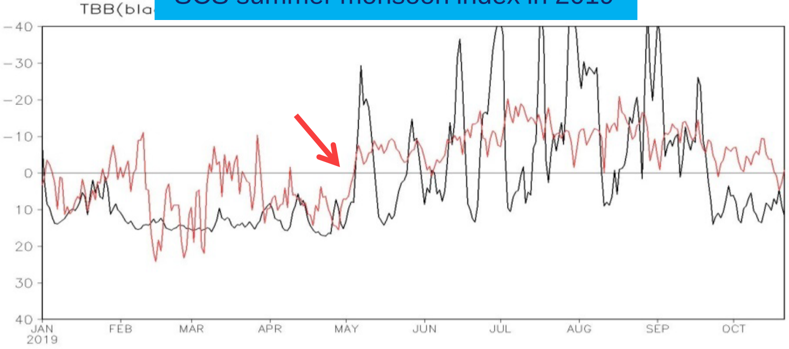
Time series of TBB in BOB summer monsoon region in 2019



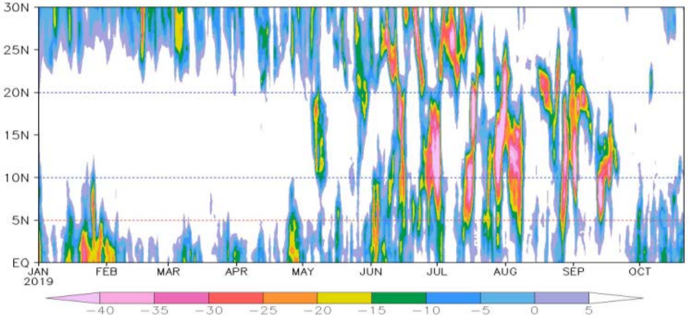
SCS: (110-120E; 10-20N)

BOB: (80-100E; 10-20N)

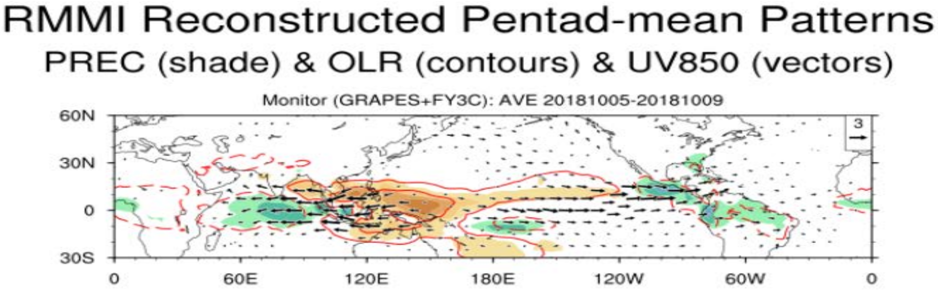
SCS summer monsoon index in 2019

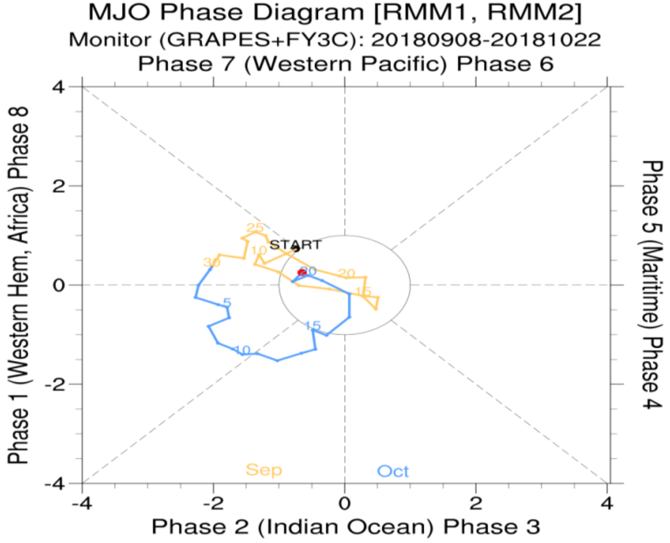


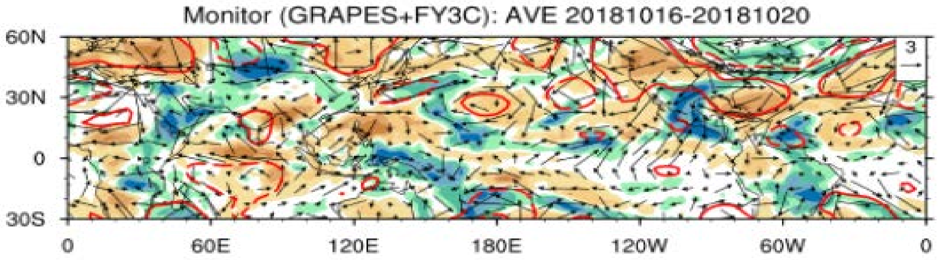
Time series of TBB in SCS summer monsoon region in 2019

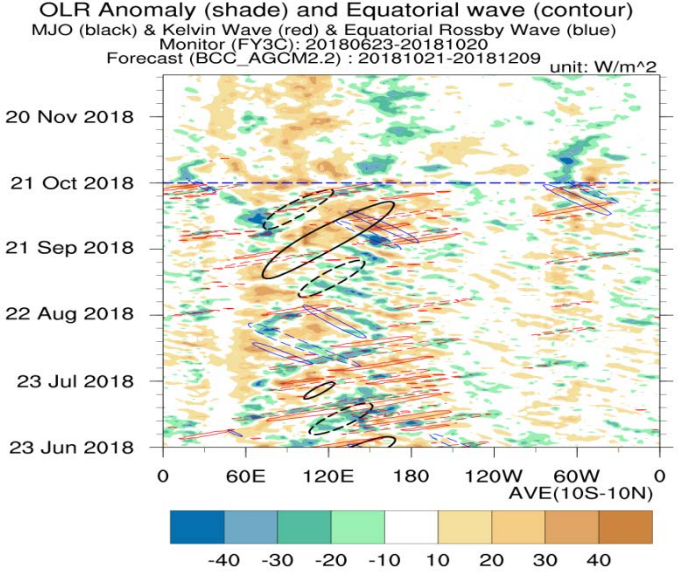


MJO monitoring using FY-3C OLR


RMMI Reconstructed Pentad-mean Patterns
PREC (shade) & OLR (contours) & UV850 (vectors)
Monitor (GRAPES+FY3C): AVE 20181005-20181009
60N
30N
0
30S
0
60E
120E
180E
120W
60W
0
3

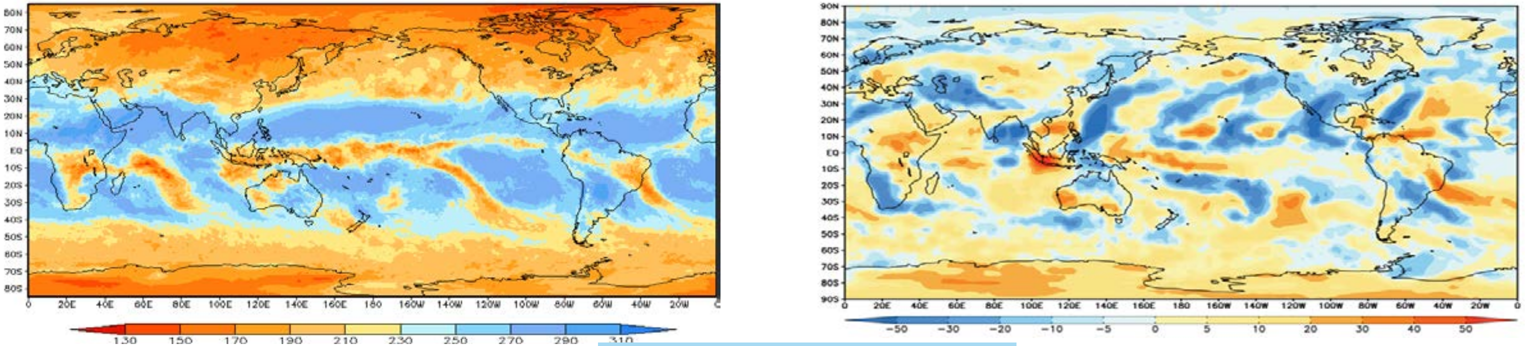



Monitor (GRAPES+FY3C): AVE 20181016-20181020
60N
30N
0
30S
0
60E
120E
180E
120W
60W
0
3

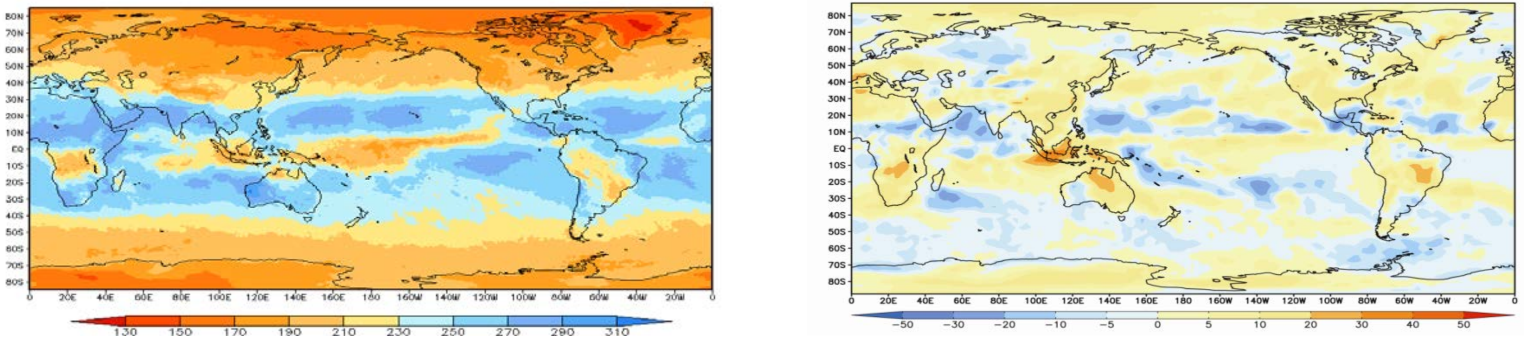


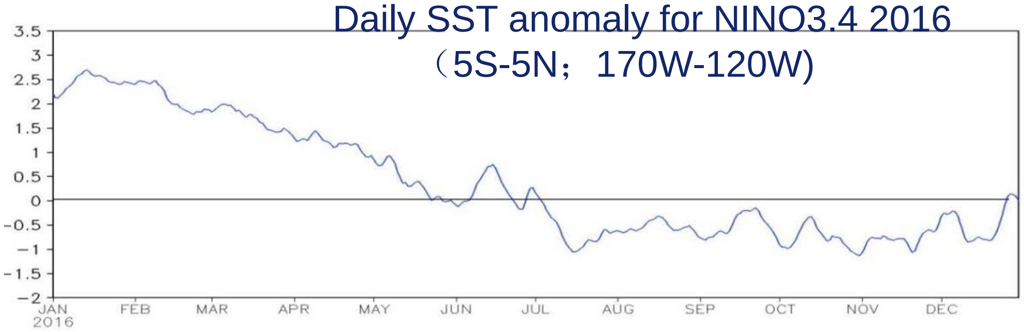
tropical convective activity monitoring

5-day OLR & Anomaly

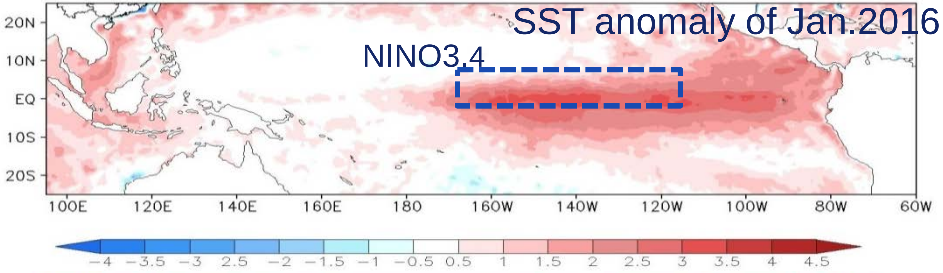

80N 70N 60N 50N 40N 30N 20N 10N EQ 10S 20S 30S 40S 50S 60S 70S 80S
0 20E 40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W 60W 40W 20W 0
130 150 170 190 210 230 250 270 290 310
90N 80N 70N 60N 50N 40N 30N 20N 10N EQ 10S 20S 30S 40S 50S 60S 70S 80S 90S
−50 −30 −20 −10 −5 0 5 10 20 30 40 50

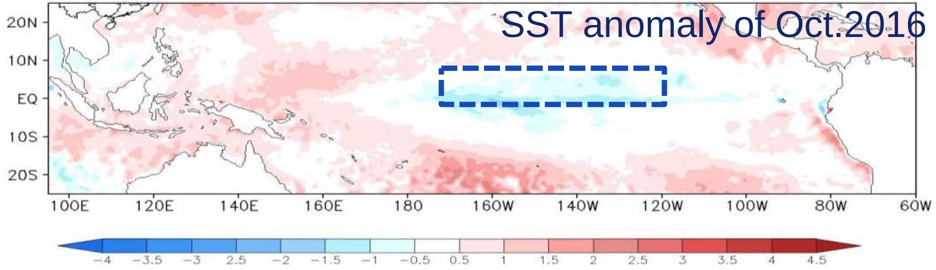
Monthly OLR & Anomaly

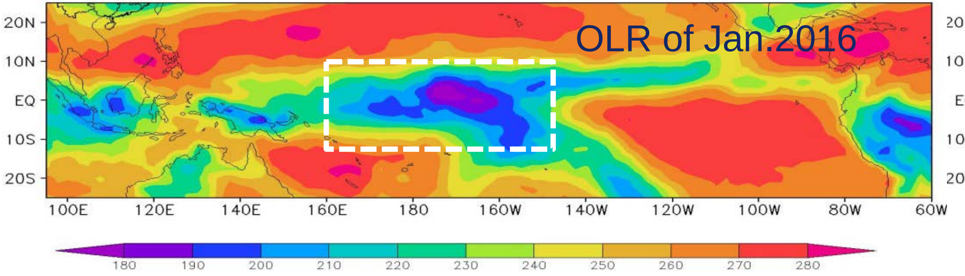

80N 70N 60N 50N 40N 30N 20N 10N EQ 10S 20S 30S 40S 50S 60S 70S 80S
0 20E 40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W 60W 40W 20W 0
130 150 170 190 210 230 250 270 290 310
−50 −30 −20 −10 −5 0 5 10 20 30 40 50

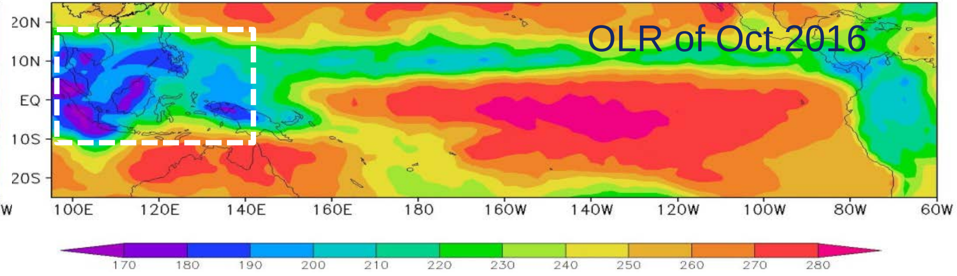

Daily SST anomaly for NINO3.4 2016
（5S-5N；170W-120W)

Mid-east Pacific Ocean shows significantly high SST in the first half of 2016，indicating the phenomenon of El Nino. Started from May, SST gradually appears negative, transferring to La Nina.


SST anomaly of Jan.2016
NINO3.4
20N
10N
EQ
10S
20S
100E
120E
140E
160E
180
160W
140W
120W
100W
80W
60W
−4
−3.5
−3
2.5
−2
−1.5
−1
−0.5
0.5
1
1.5
2
2.5
3
3.5
4
4.5


SST anomaly of Oct.2016
20N
10N
EQ
10S
20S
100E
120E
140E
160E
180
160W
140W
120W
100W
80W
60W
−4
−3.5
−3
2.5
−2
−1.5
−1
−0.5
0.5
1
1.5
2
2.5
3
3.5
4
4.5


OLR of Jan.2016
20N
10N
EQ
10S
20S
100E
120E
140E
160E
180
160W
140W
120W
100W
80W
60W
180
190
200
210
220
230
240
250
260
270
280


OLR of Oct.2016
20N
10N
EQ
10S
20S
100E
120E
140E
160E
180
160W
140W
120W
100W
80W
60W
170
180
190
200
210
220
230
240
250
260
270
280

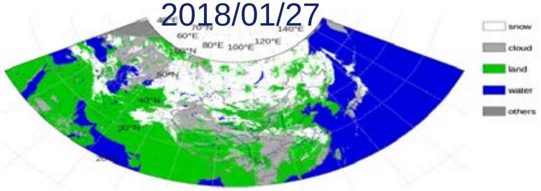
During El Nino, convections occur at mid-east Pacific Ocean.

During La Nina, convections occur around South China Sea and Philippine.

Snow Cover Days in Asia/China

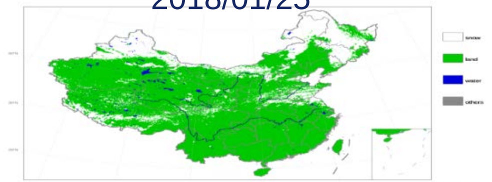
FY4A / Multi-Combined Satellite Data /IMS

2018/01/27


70°N
60°E
80°E
100°E
120°E
140°E
50°N
40°N
30°N
snow
cloud
land
water
others

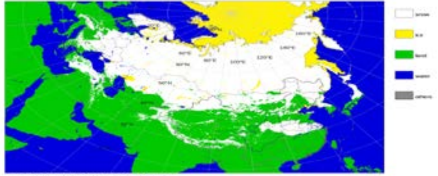
Daily Snow Cover Over China on 2018-02-01
Datasource:FY4A Snow Cover

2018/01/25


snow
land
water
others

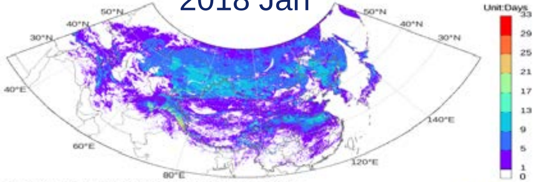
Daily Snow Cover Over China on 2018-01-25
Datasource:Multi-Combined Snow Cover

2018/01/25


snow
ice
land
water
others

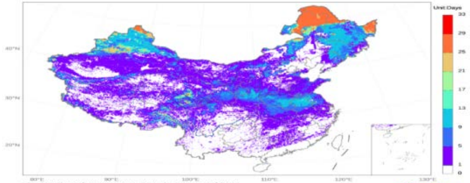
Daily Snow Cover Over China on 2018-01-25
Datasource:IMS Snow Cover

2018 Jan


50°N
40°N
30°N
40°E
60°E
80°E
120°E
140°E
Unit:Days
33
29
25
21
17
13
9
5
1
0

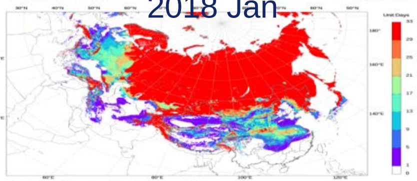
The Number of Snow Cover Days in January of 2018
Datasource:FY4A Snow Cover
Produced:2018-06-19 08:03:10

2018 Jan


Unit:Days
33
29
25
21
17
13
9
5
1
0
20°N
80°E
90°E
100°E
110°E
120°E
130°E

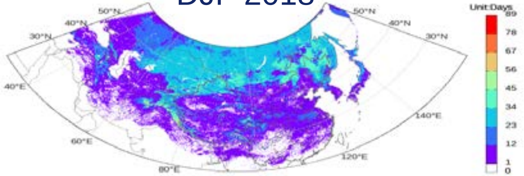
The Number of Snow Cover Days in January of 2018
Datasource:Multi-Combined Snow Cover

2018 Jan


30°N
40°N
50°N
60°N
80°N
90°N
180°
Unit:Days
33
29
25
21
17
13
9
5
1
0
60°E
80°E
100°E
120°E

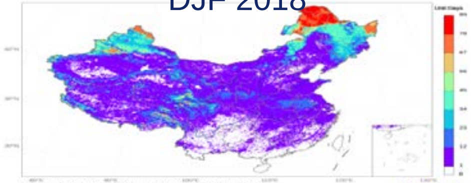
The Number of Snow Cover Days in January of 2018
Datasource:IMS Snow Cover

DJF 2018


50°N
40°N
30°N
40°E
60°E
80°E
120°E
140°E
Unit:Days
89
78
67
56
45
34
23
12
1
0

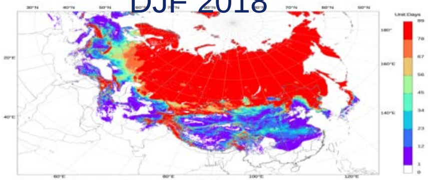
The Number of Snow Cover Days in Winter of 2017-2018
Datasource:FY4A Snow Cover

DJF 2018



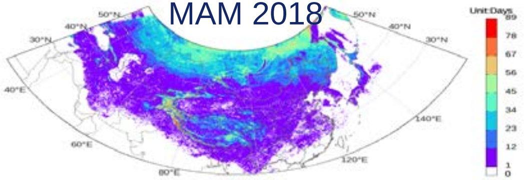
The Number of Snow Cover Days in Winter of 2017-2018
Datasource:Multi-Combined Snow Cover

DJF 2018


30°N
40°N
50°N
70°N
80°N
90°N
180°
Unit:Days
89
78
67
56
45
34
23
12
1
0

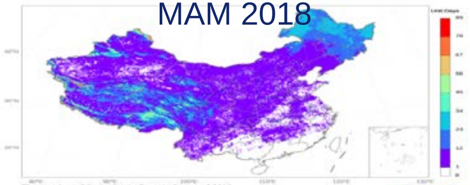
The Number of Snow Cover Days in Winter of 2017-2018
Datasource:IMS Snow Cover

MAM 2018


50°N
40°N
30°N
40°E
60°E
80°E
120°E
140°E
Unit:Days
89
78
67
56
45
34
23
12
1
0

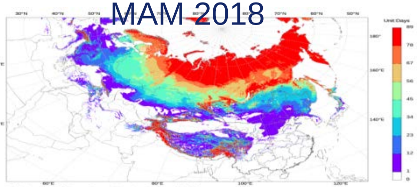
The Number of Snow Cover Days in Spring of 2018
Datasource:FY4A Snow Cover

MAM 2018



The Number of Snow Cover Days in Spring of 2018
Datasource:Multi-Combined Snow Cover

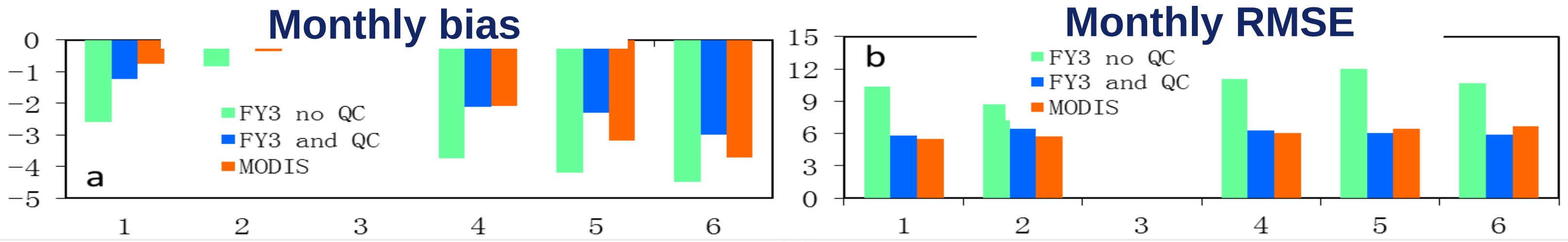
MAM 2018



The Number of Snow Cover Days in Spring of 2018
Datasource:IMS Snow Cover

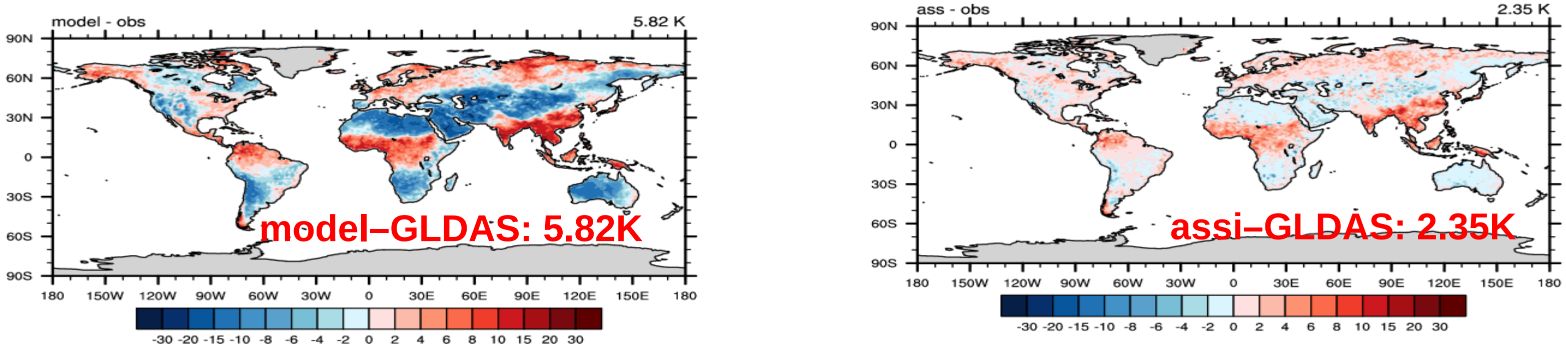
3 FY data in Climate model

1) FY-3 Land surface temperature assimilation test


Monthly bias

Monthly RMSE

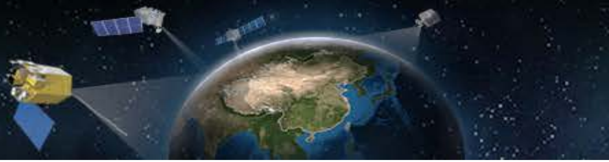
Global mean monthly bias and RMSE of FY3 (**before** and **after** QC) and **MODIS** vs GLDAS

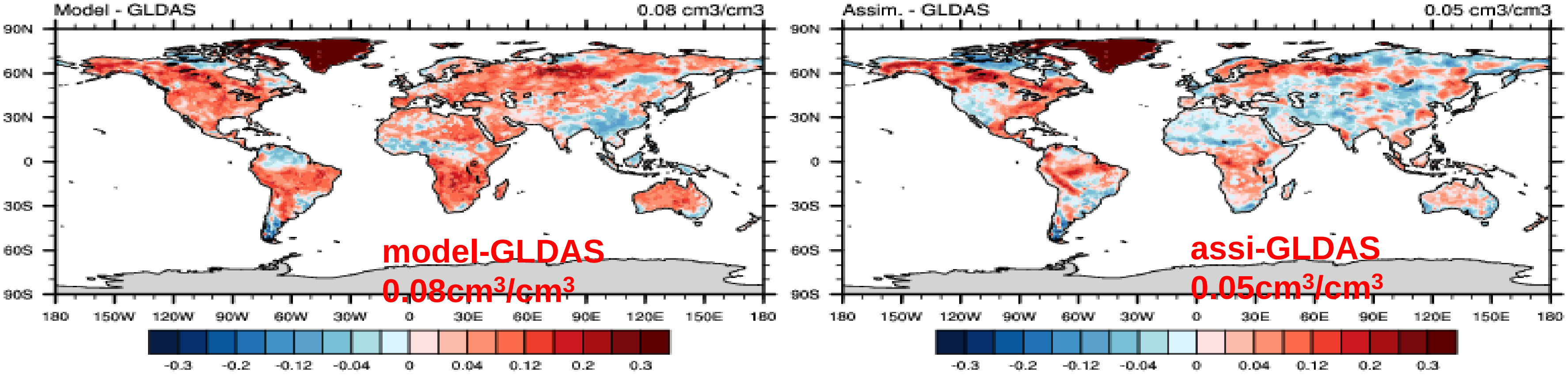

model - obs
5.82 K
90N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
-30 -20 -15 -10 -8 -6 -4 -2 0 2 4 6 8 10 15 20 30
model–GLDAS: 5.82K
ass - obs
2.35 K
90N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
-30 -20 -15 -10 -8 -6 -4 -2 0 2 4 6 8 10 15 20 30
assi–GLDAS: 2.35K

Global mean monthly bias distribution of before (left) and after (right) assimilation

- Based on FY3, the LST data assimilation test system was established in BCC.
- After QC and BC, the quality of FY3/LST data is comparable to MODIS, and can meet the needs of quantitative application in BCC model.
- After assimilation, the global mean bias of LST is reduced by about 3K.

2) FY-3 Soil moisture assimilation test




Model - GLDAS
0.08 cm3/cm3
Assim. - GLDAS
0.05 cm3/cm3
90N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
-0.3
-0.2
-0.12
-0.04
0
0.04
0.12
0.2
0.3

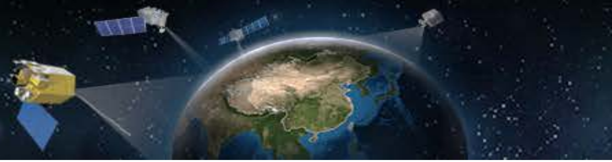
model-GLDAS $0.08 cm^3/cm^3$

assi-GLDAS $0.05 cm^3/cm^3$

Global mean monthly bias distribution of model (left) and assimilation (right) soil moisture

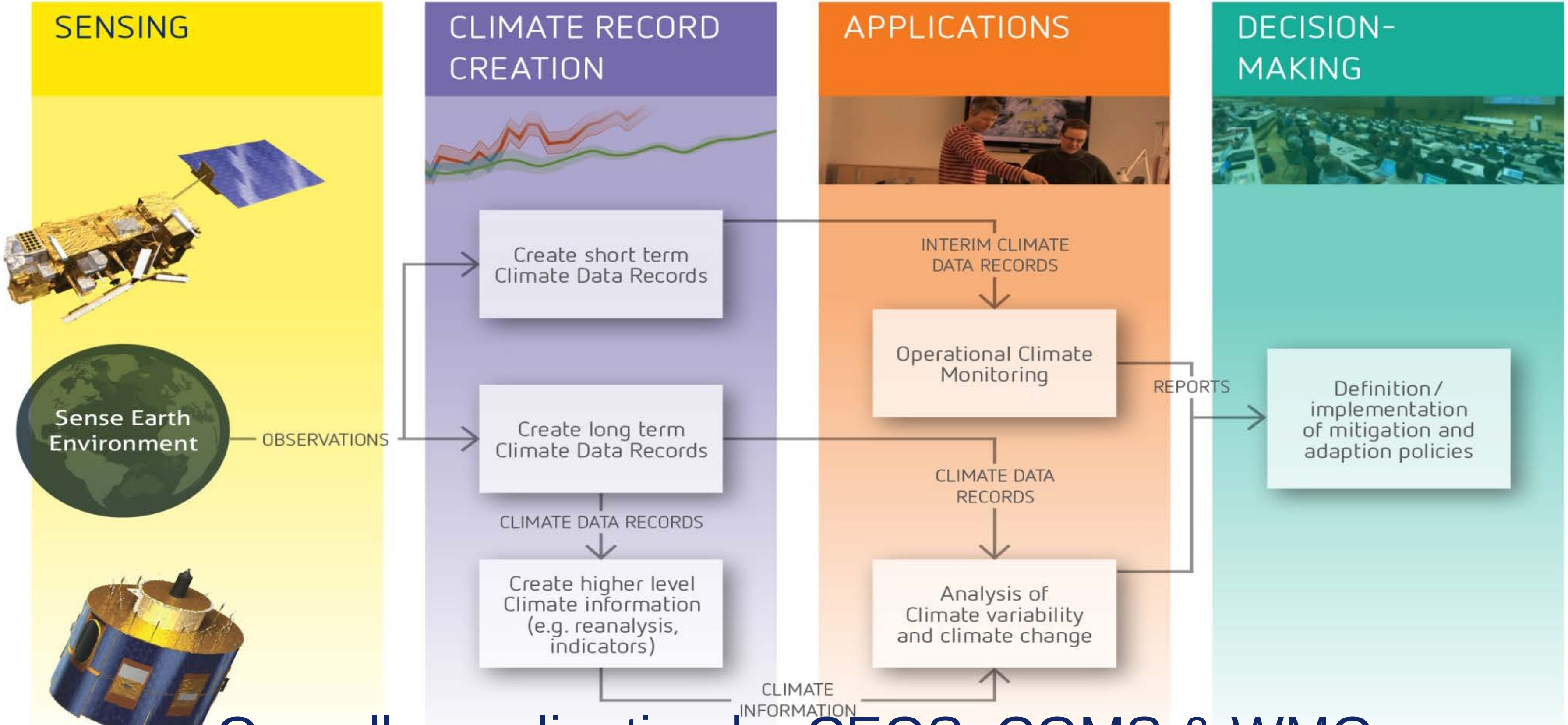
- The soil moisture data assimilation test system was also established in BCC.
- Assimilating FY3 soil moisture products can effectively improve the simulation of BCC_AVIM model, and significantly reduced the overall soil moisture bias and errors.

CRA-40:CMA Global Reanalysis



- **Started in early 2014, lead by the NMIC of CMA**
  - **3 other CMA national centers and 3 outside institutes involved:**
    - **NMC, NSMC, NCC, CAS/IAP, BNU, NUIST**
- **Include Atmosphere and Land component**
- **Produce 40-year datasets (1979-2018) :**
  - **Ingested observations**
  - **Grid products: ~30km, 6 hourly**
  - **Obs. feedback datasets : departure from analysis & background**
  - **Atmospheric Reanalysis uncertainty : from EnKF ensembles**
- **Will then be continuously running in NRT for climate monitoring**

Implementation of Climate Monitoring from space



SENSING

Sense Earth Environment

OBSERVATIONS

CLIMATE RECORD CREATION

Create short term Climate Data Records

Create long term Climate Data Records

CLIMATE DATA RECORDS

Create higher level Climate information (e.g. reanalysis, indicators)

CLIMATE INFORMATION

APPLICATIONS

INTERIM CLIMATE DATA RECORDS

Operational Climate Monitoring

CLIMATE DATA RECORDS

Analysis of Climate variability and climate change

REPORTS

DECISION-MAKING

Definition/ implementation of mitigation and adaption policies

Overall coordination by CEOS, CGMS & WMO

Thanks for your Attention