Utilization of cloud retrievals at CMA

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National Satellite Meteorological Center ,CMA

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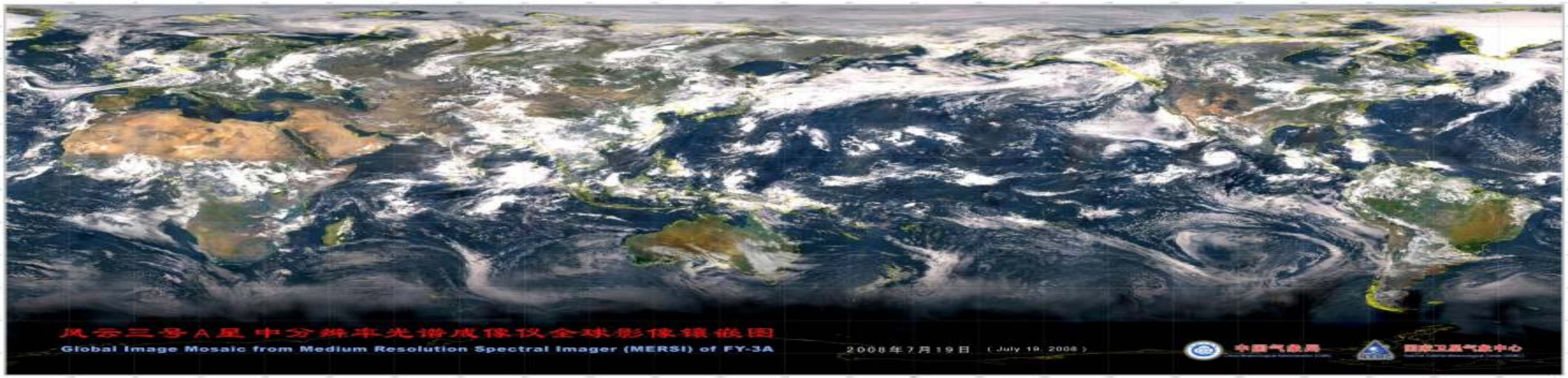
- **Satellite Programs & Major Payloads**
- **Cloud Retrieval and Validation in CMA**
- **Forward look**

The Roadmap of CMA Fengyun Satellites

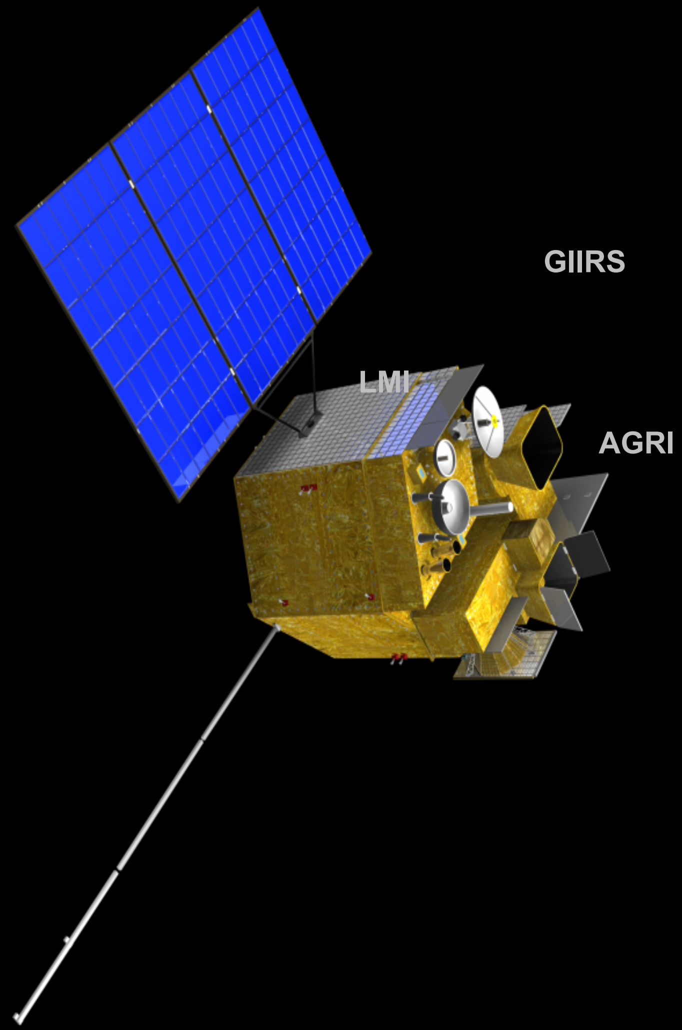
Since Jan. 1969, China began to develop his own meteorological Satellite				
Leo	**Launch Data**		**Geo**	**Launch Data**
FY-1A	**Sept. 7, 1988**		**FY-2A**	**Jun. 10, 1997**
FY-1B	**Sept. 3, 1990**		**FY-2B**	**Jun. 25, 2000**
FY-1C	**May 10, 1999**		**FY-2C**	**Oct. 18, 2004**
FY-1D	**May 15, 2002**		**FY-2D**	**Dec. 8, 2006**
FY-3A	**May 27, 2008**		**FY-2E**	**Dec. 23, 2008**
FY-3B	**Nov 5, 2010**		**FY-2F**	**Jan. 13, 2012**
FY-3C	**Sept 23, 2013**		**FY-2G**	**2014**
FY-3D	**2015**		**FY-2H** **FY-4A**	**2016**

FengYun LEO. Satellites: FY-3 A/B

11 instruments on board FY-3A/B, including:
VIRR: Visible and Infra-Red Radiometer
MERSI： Medium Resolution Spectral Imager
IRAS： Infrared Atmospheric Sounder
MWTS： MicroWave Temperature Sounder
MWHS: MicroWave Humidity Sounder
MWRI: MicroWave Radiation Imager
SBUS: Solar Backscatter Ultraviolet Sounder
TOU: Total Ozone mapping Unit
SIM: Solar Irritation Monitor
ERM: Earth Radiation Monitor
SEM: Space Environment Monitor



FengYun GEO. Satellites: FY-4



Spacecraft:

1. Launch Weight: approx. 5300kg
2. Stabilization: Three-axis
3. Attitude accuracy: 3″
4. Bus: 1553B+Spacewire
5. Raw data transmission : X band
6. Output power: >= 3200W
7. Design life: over 7 years

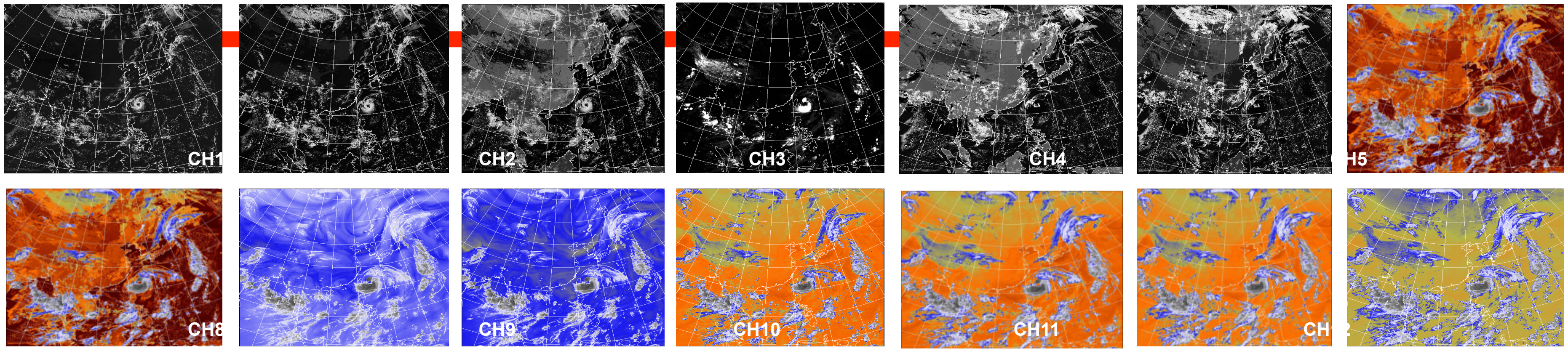
Main instrument

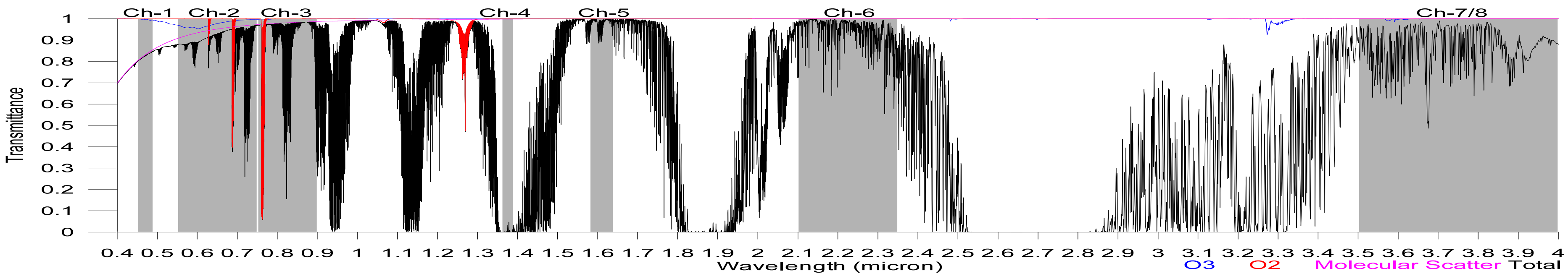
1) GIIRS: Geo. Interferometric Infrared Sounder
2) AGRI: Advanced Geosynchronous Radiation Imager
3) LMI: Lightning Mapping Imager
4) SEP: Space Environment Package

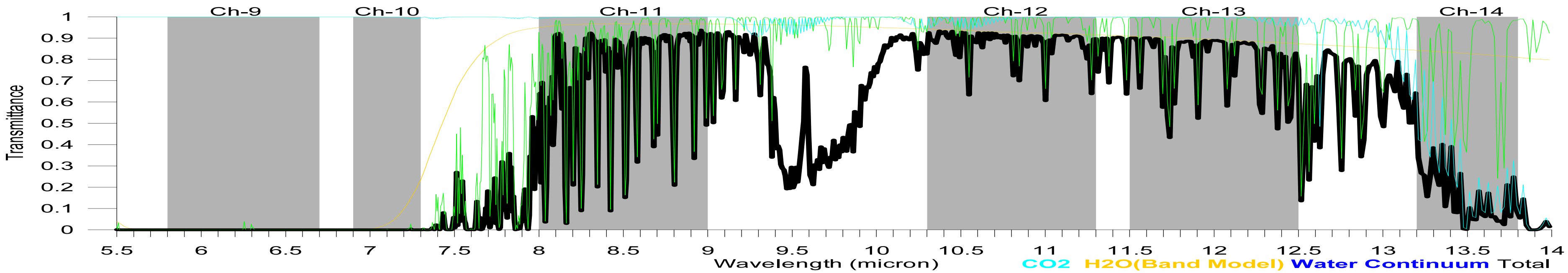
FengYun GEO. Satellites: Imager

	FY-2 F/G/H VISSR			FY-4A AGRI			
Channel	Band	Spatial Resolution	Sensitivity	Band	Spatial Resolution	Sensitivity	Main Application
Visible & Near -Infrared				0.45～0.49	1	S/N≥90 (ρ=100%)	Aerosol
	0.55～0.75	1.25	2.3 @ρ=1%	0.55～0.75	0.5～1	S/N≥200 (ρ=100%)	Fog, Clound
				0.75～0.90	1	S/N≥5(ρ=1%)@0.5Km	Vegetation
Short -wave Infrared				1.36～1.39	2	S/N≥200 (ρ=100%)	Cirrus
				1.58～1.64	2	S/N≥200 (ρ=100%)	Cloud,Snow
				2.1～2.35	2～4		Cirrus,Aerosol
Mid-wave Infrared				3.5～4.0(High)	2	NEΔT≤0.7K(300K)	Fire
	3.5～4.0	5	0.22K@300K	3.5～4.0(Low) *	4	NEΔT≤0.2K(300K)	Land surface
Water Vapor				5.8～6.7	4	NEΔT≤0.3K(260K)	WV
	6.3～7.6	5	0.30K@260K	6.9～7.3	4	NEΔT≤0.3K(260K)	WV
Long-wave Infrared				8.0～9.0*	4	NEΔT≤0.2K(300K)	WV,Cloud
	10.3～11.3	5	0.12K@300K	10.3～11.3*	4	NEΔT≤0.2K(300K)	SST
	11.5～12.5	5	0.16K@300K	11.5～12.5*	4	NEΔT≤0.2K(300K)	SST
				13.2～13.8*	4	NEΔT≤0.5K(300K)	Clound,WV

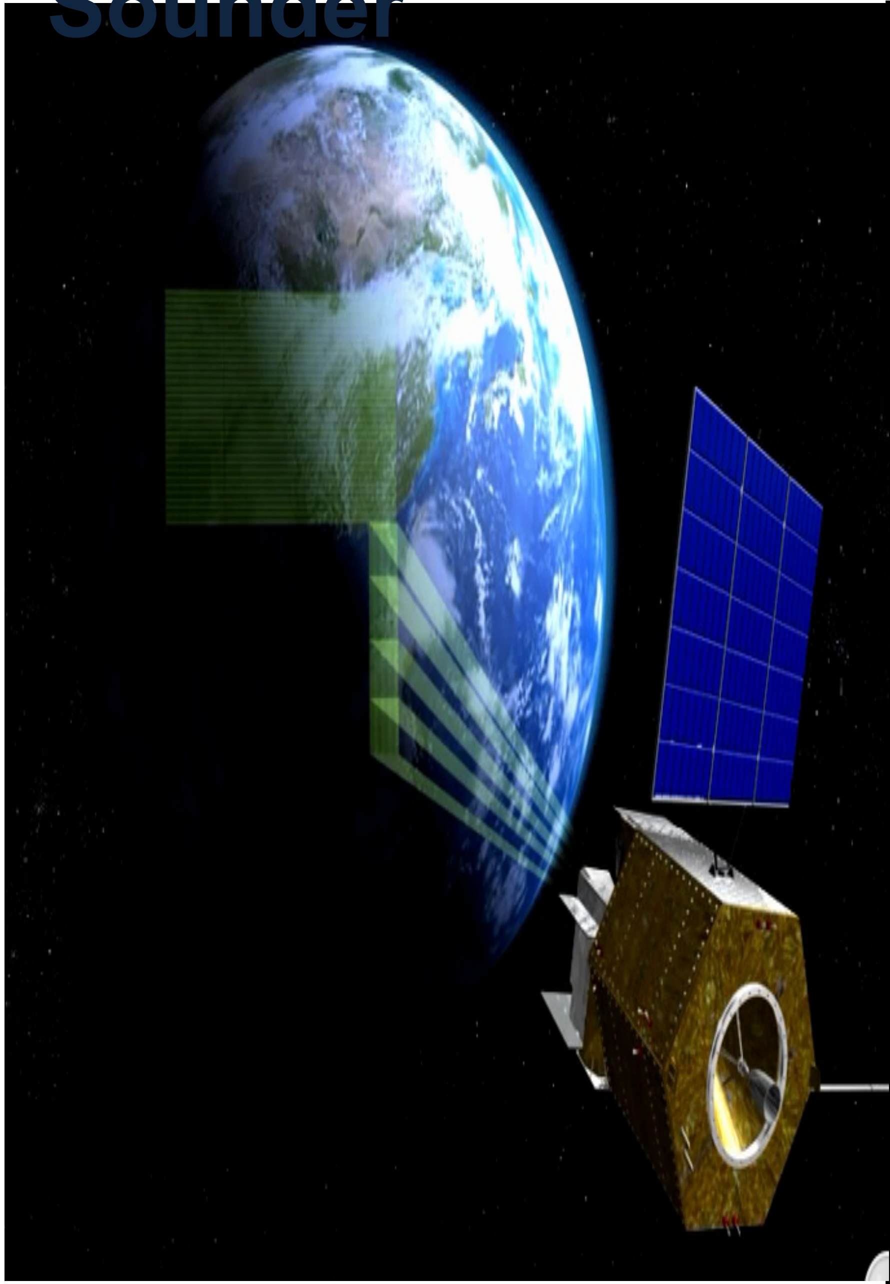
FY-4A AGRI Channels







GIIRS: Geo. Interferometric Infrared Sounder



	FY-4A (R&D)	FY-4B (Operational)
Spectral Parameters (Normal mode)	Range Resolution Channels LWIR: 700-1130 Cm -1 0.8 538 S/MIR:1 650-2250Cm -1 1.6 375 VIS : 0.55-0.75 μm 1	Range Resolution Channels LWIR: 700-1130 0.625 688 S/MIR:1 650-2250 1.2 500 VIS : 0.55-0.75 μm 1
Spatial Resolution	LWIR/S/MIR : 16Km SSP VIS : 2Km SSP	LWIR/S/MIR : 8Km SSP
Operational Mode	China area 5000 × 5000 Km2 Mesoscale area 1000 × 1000 Km2	China area 5000 × 5000 Km2 Mesoscale area 1000 × 1000 Km2
Temporal Resolution	China area <1 hr Mesoscale area <½ hr	China area <1 hr Mesoscale area <½ hr
Sensitivity (mW/m2sr cm-1)	LWIR: 0.5 -1.1 S/MIR: 0.1-0.14 VIS: S/N>200(ρ=100%)	LWIR: 0.3 S/MIR: 0.06
Calibration accuracy	1.5k (3σ) radiation	1.0k (3σ)
Calibration accuracy	10 ppm (3σ) spectrum	5 ppm (3σ)
Quantization Bits	13 bits	13 bits

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L2 Cloud Products of FengYun LEO.

FY-3A/B(R&D)	FY-3C（OP)
Cloud Detection	Cloud Detection
Total Cloud Amount	Total Cloud Amount
Cloud top height/pressure	Cloud top height/pressure
Cloud phase	Cloud phase
Cloud classification(low,middle & high cloud,cirrus)	Cloud classification(low,middle & high cloud,cirrus)
Cloud optical thickness	Cloud optical thickness

FY3 Channel used for cloud mask

Band	Wave length	Band	Wave length	Used in Cloud Mask
FY3/MERSI		**MODIS**		
1	0.47	3	0.465	N
2	**0.55**	**4**	**0.55**	**Y**
3	**0.65**	**1**	**0.65**	**Y**
4	**0.865**	**2**	**0.86**	**Y**
5	**11.25**	**31**	**11**	**Y**
6	0.412	8	0.41	N
7	0.443	9	0.44	N
8	0.49	10	0.485	N
9	0.52	11	0.53	Y
10	0.565	12	0.55	N
11	0.65	13	0.665	N
12	0.685	14	0.675	N
13	0.765	15	0.75	N
14	0.865	16	0.87	N
15	**0.905**	**17**	**0.9**	**Y**
16	**0.94**	**18**	**0.94**	**Y**
17	0.98			N
18	1.03			N
19	**1.64**	**6**	**1.64**	**Y**
20	**2.13**	**7**	**2.1**	**Y**

Band	Wave length	Band	Wave length	Used in Cloud Mask
FY3/VIRR		**MODIS**		
1	**0.63**	**1(250m)**	**0.659**	**Y**
2	**0.86**	**2(250m)**	**0.865**	**Y**
3	**3.7**	**20**	**3.75**	**Y**
4	**10.8**	**31**	**11**	**Y**
5	**12**	**32**	**12**	**Y**
6	**1.6**	**6(500m)**	**1.64**	**Y**
7	0.45	9	0.44	N
8	0.5	10	0.485	N
9	0.55	4(500m)	555	N
10	**1.35**	**26**	**1.375**	**Y**

FY3/MERSI cloud mask(daytime only)

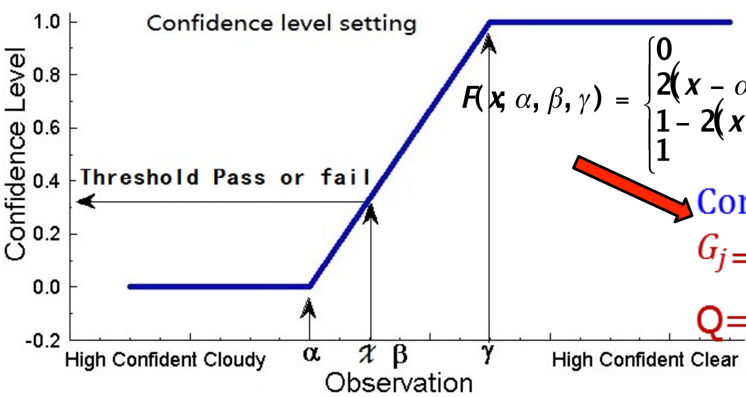
The Algorithm based on the MODIS cloud mask algorithm .

It was used in National Satellite Meteorological Center (NSMC) on April 3, 2007.

From March 31 on to April 7 ,2007, and form August 3 to August 22 ,2009, Mr. Richard Frey had been invited to work on MERSI Algorithm in the China meteorological administration national satellite meteorological center.

Reference:

Discriminating clear-sky from cloud with MERSI Algorithm theoretical basis document(MERSI_ATBD_0207). Steve Ackerman, Richard Frey, Kathleen Strabala, and Jun Li. April 2007.

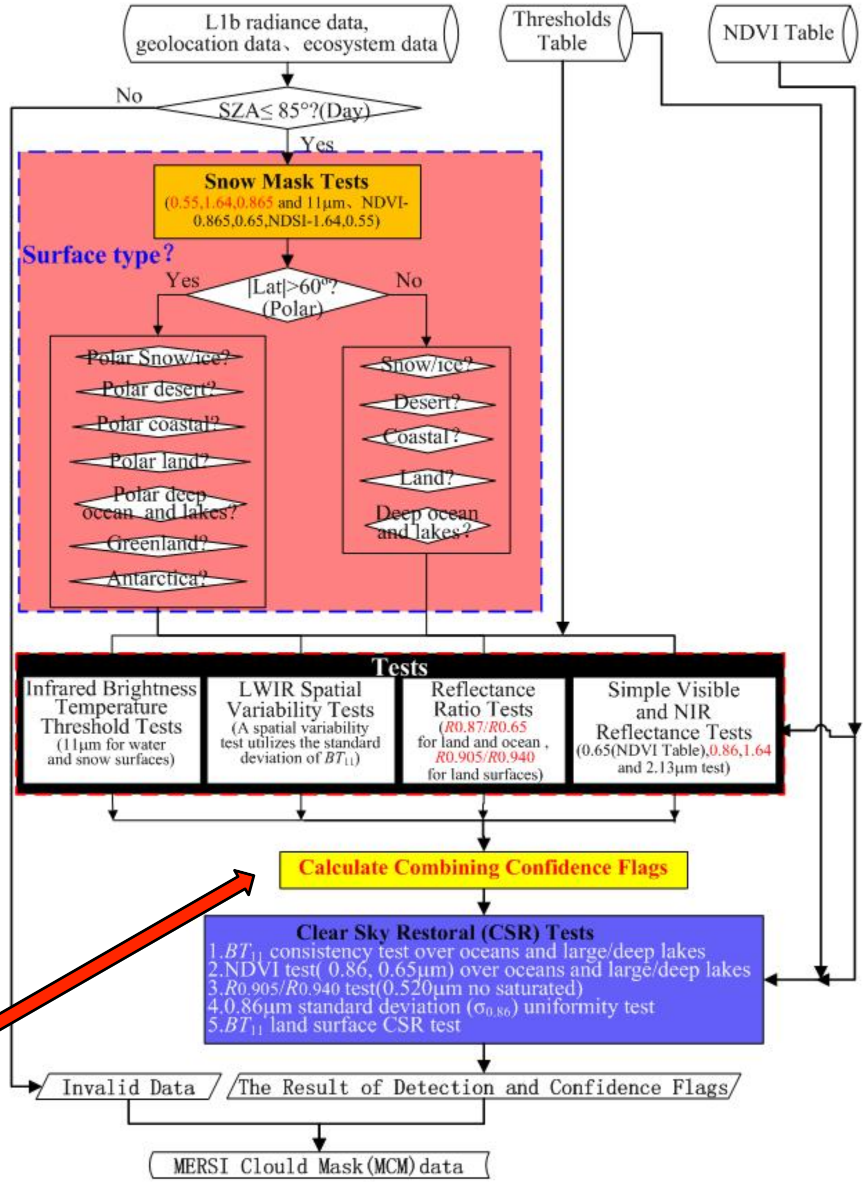


$$F(x;\alpha,\beta,\gamma)=\begin{cases}0 & (x\le\alpha)\\ 2\left((x-\alpha)/(\gamma-\alpha)\right)^2 & (\alpha\le x\le\beta)\\ 1-2\left((x-\alpha)/(\gamma-\alpha)\right)^2 & (\beta\le x\le\gamma)\\ 1 & (\alpha\le\gamma)\end{cases}$$

Confidence Flags:

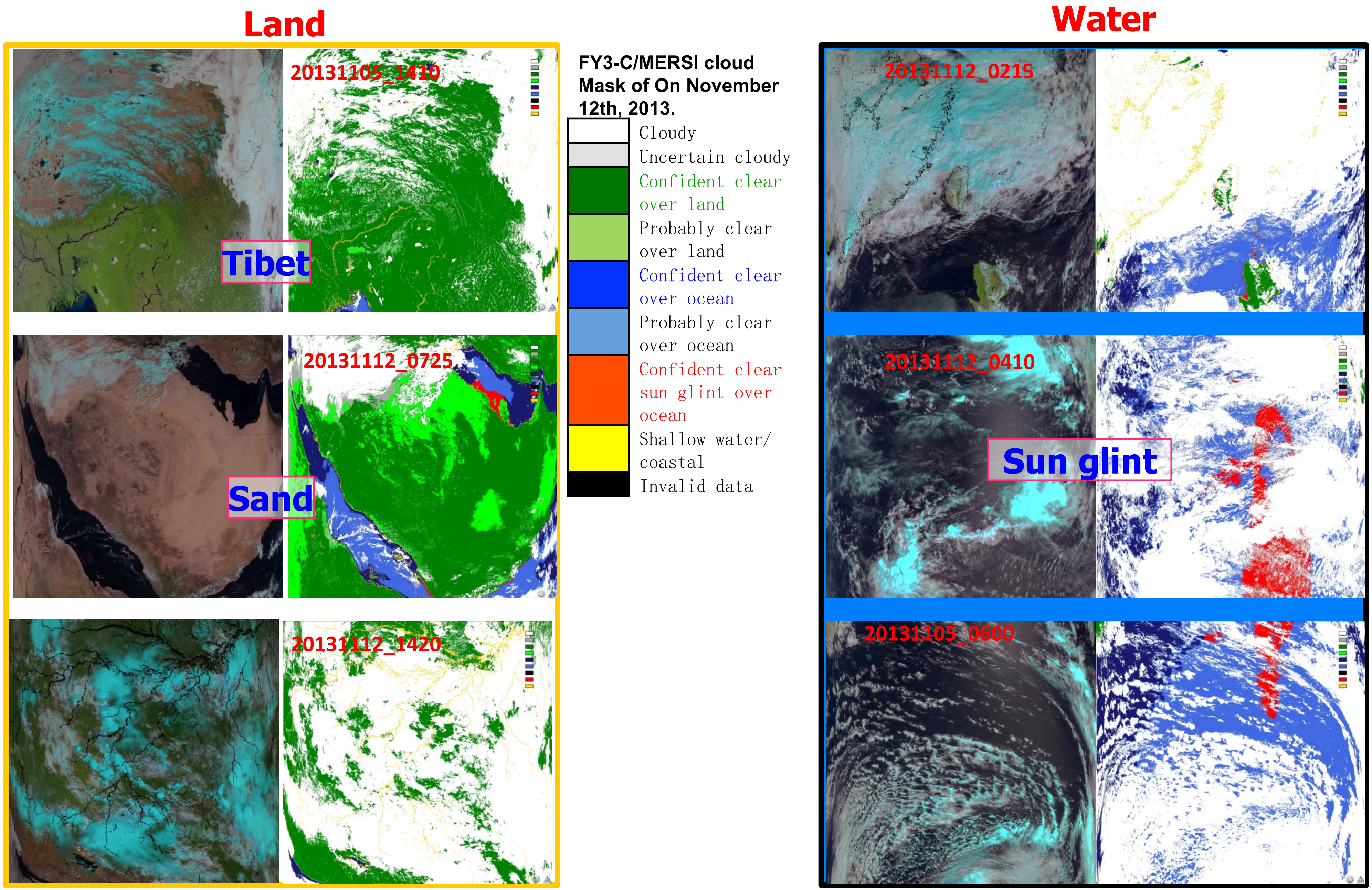
$$G_{j=1,5}=\min[F_i]$$

$$Q=\sqrt[N]{\prod_{j=1}^{N} G_j}$$



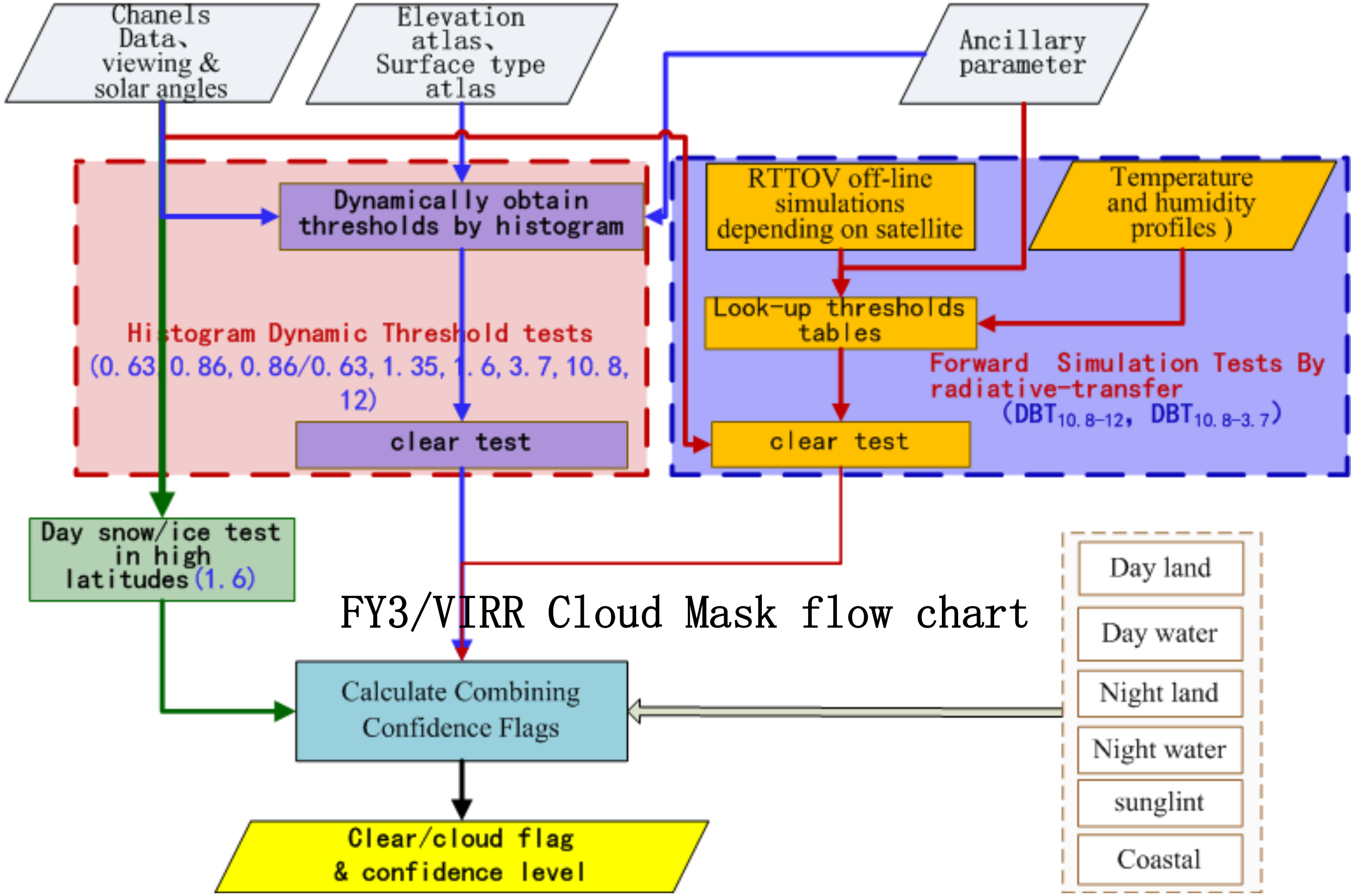
clear-sky confidence values: 0, >.66, >.95 and >.99

FY3/MERSI cloud mask(daytime only)



FY3/VIRR cloud mask

Based on the dynamic thresholds algorithm and Radiative-transfer Method



FY3/VIRR Cloud Mask flow chart

Referrence:

①Alan. V. Di Vittorio, Emery, W.J.. 2002: An automated dynamic threshold cloud-masking algorithm for daytime AVHRR images over land [J]. IEEE Transactions on Geoscience and Remote Sensing, 40(8): 1682-1694.

②Liu Xi, Xu Jianmin, Du Bingyu. 2005:A bi-channel dynamic threshold algorithm used in automatically identifying clouds on GMS-5 imagery. Journal of applied meteorological science Vol.16, No.4 16(4):434-444.

③Eyre J. 1991:A fast radiative transfer model for satellite soundings systems. ECMWF Res.Dep.Tech.Mem 176. ECMWF, Reading, United Kingdom.

Among all bands, 0.63,0.86,1.35 and 1.6μm bands are used only for the Day.

Confidence value= ∑clear tests passed/∑clear tests in a test serie

confident_clear(Confidence value >0.75) , probably_clear(Confidence value >0.50)

probably_cloudy(Confidence value >0.25) ,confident_cloudy(Confidence value >0)

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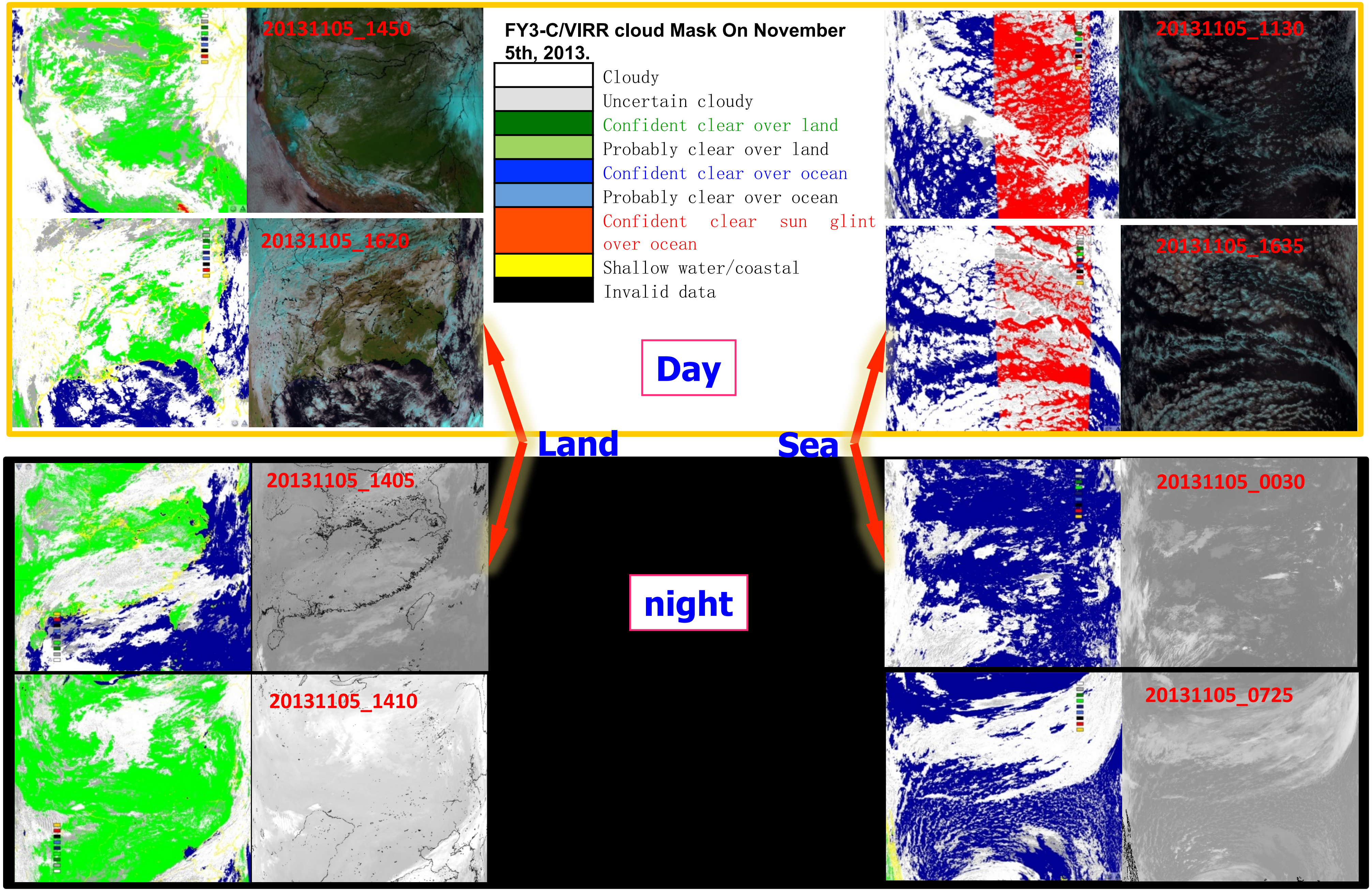
FY3/VIRR cloud mask



FY3 MERSI/VIRR cloud mask validation based on ground observation.

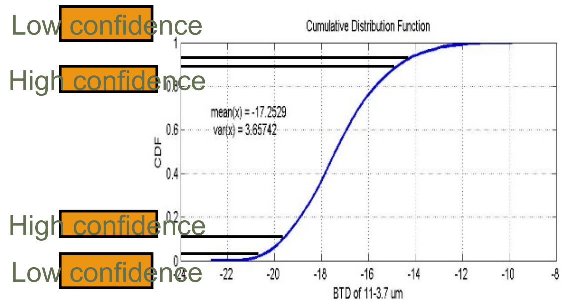
Data source ground observation
FY-3B/VIRR Data
Time : December 19, 2010 ~ January 10, 2011.
view angle < 30 degree
Clearsky: cloud amount =0%
Cloud: cloud amount >=80%

	Dec 19th,2010~Jan 10th,2011		
	Total samples	Correct samples	Accuracy
VIRR	**1055**	**754**	**71.47%**
MERSI	**516**	**420**	**81.40%**

FY3 dust product flow chart

Spectral clustering → BTD → Spectral Ratio → Background → STD

Spectral clustering	BTD	Spectral Ratio	Background	STD
R0.64um R0.47um TBB11um 3.7um R1.38um	BTD11-12um BTD11-3.7um	NDSI NDVI $R_{0.4}/R_{0.64}$ NDDI ICSD	11um BK	STD of Ref



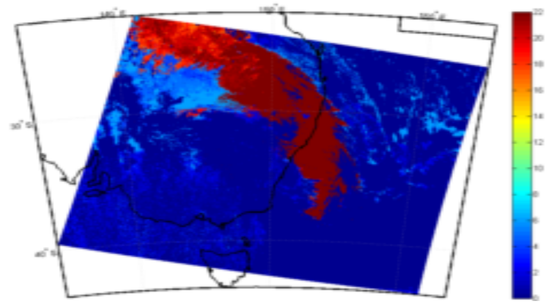
GOES-R

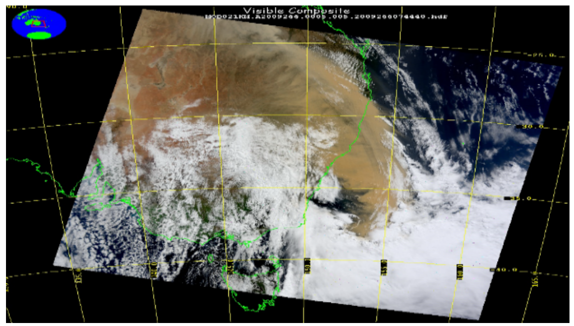
Future GOES Imager (ABI) Band	Nominal Wavelength Range (µm)	Sample Use
1	0.45-0.49	Dust/Smoke
2	0.59-0.69	Dust/Smoke
3	0.846-0.885	Dust/Smoke
4	1.371-1.386	Dust/Smoke
5	1.58-1.64	SMOKE
6	2.225 - 2.275	Smoke
7	3.80-4.00	Dust/Smoke
8	5.77-6.6	
9	6.75-7.15	
10	7.24-7.44	
11	8.3-8.7	
12	9.42-9.8	
13	10.1-10.6	
14	10.8-11.6	Dust/Smoke
15	11.8-12.8	Dust/Smoke
16	13.0-13.6	

FY3 and FY-4 dust product

Channel	Band （μm）	Use
1	0.45～0.49	Dust
2	0.55～0.75	Dust
3	0.75～0.90	Dust
4	1.36～1.39	Dust
5	1.58～1.64	Dust
6	2.1～2.35	Dust
7	3.5～4.0(high)	Dust
8	3.5～4.0(low)	
9	5.8～6.7	
10	6.9～7.3	
11	8.0～9.0	
12	10.3～11.3	Dust
13	11.5～12.5	Dust
14	13.2～13.8	

Use MODIS data as proxy





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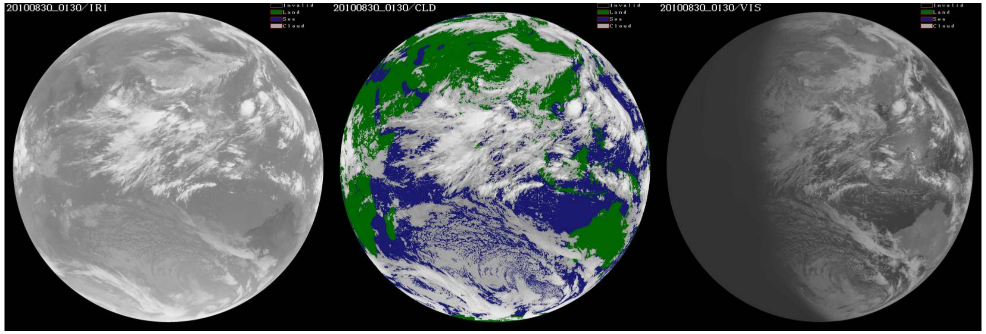
L2 Cloud Products of FengYun GEO.

FY-2 C/D/E（OP）	FY-2 F/G/H（OP）	FY-4A（R&D）
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	

FY2/VISSR cloud mask

Used channels in FY-2/VIRR Cloud Mask

channel	Central Wavelength(μm)	Filters Width(μm)
Vis	0.67	0.56~0.91
IR1	10.8	10.32~11.49
IR2	12	11.32~12.68
IR3	3.7	3.53~4.04
IR4	6.7	6.27~7.55



Four cloud detection groups used in Algorithm

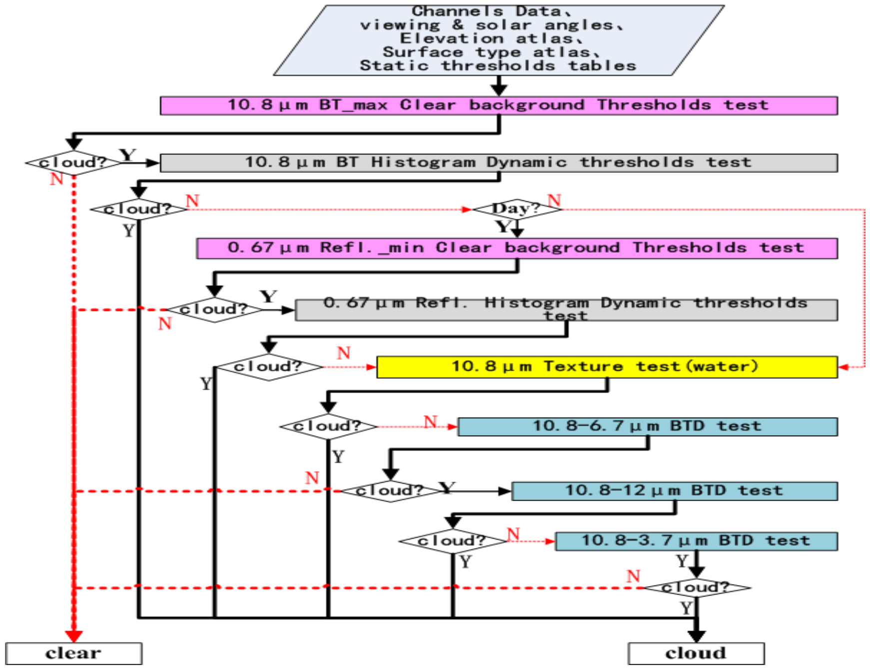
group	Cloud tests	Sea/ lake	sun glint	Land	Desert
Histogram dynamic thresholds	**Refl._0.67 (daytime)**	√	x	√	√
	BT10.8	√	√	√	√
Clear background Thresholds (15day)	**0.67μm Refl._min atlas(daytime) (Thresholds>R-Rback_min)**	√	x	√	√
	10.8μm BT_max atlas (Thresholds>BTback_max -BT)	√	√	√	√
BTD	**BTD11-3.7 (night)**	√	x	√	√
	BTD11-6.7 (high cloud)	√	√	√	√
	BTD11-12 (cirrus)	√	√	√	√
texture	Standard deviation of BT11(3*3)	√	√	x	x

BT10.8=11μm bright temperature

BTD11-3.7=BT(10.8μm)-BT(12μm) **BTD**11-6.7=BT(10.8μm)-BT(6.7μm)

Rback_min: Clear background minimum reflectance of pixel in 15 days; **R:** **real** reflectance

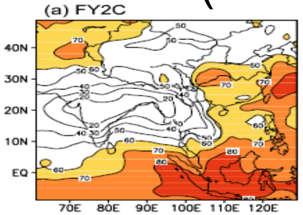
BTback_max: Clear background maximum BT of pixel in 15 days; **BT:** **real BT**



FY2 cloud detection flow chart

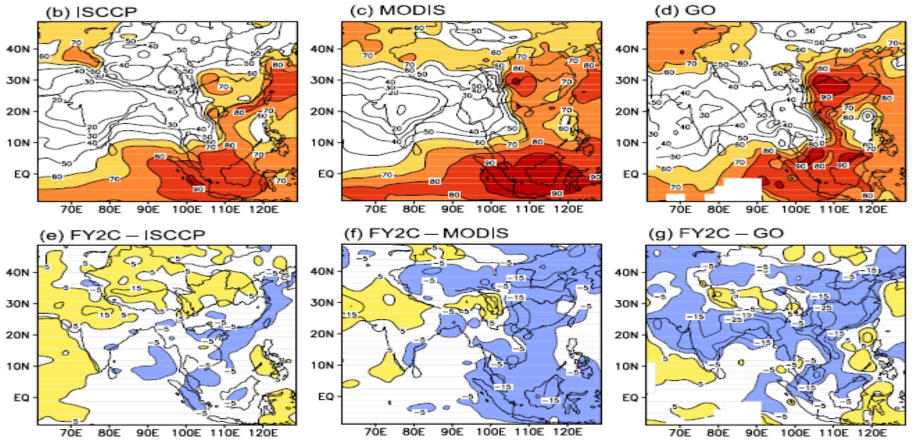
FY2 VISSR cloud mask validation

Winter (Dec-Jan-Feb)

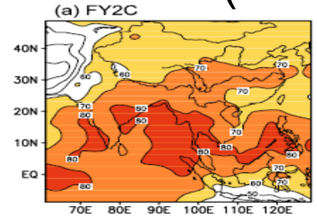


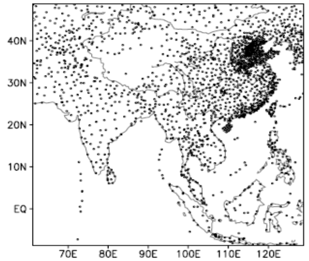
Spatial Pattern Correlation Coefficients of the Annual Mean Cloudiness for Each Two-Member Combination of the Four Data Sets: FY-2C, ISCCP, MODIS, and Ground Observation

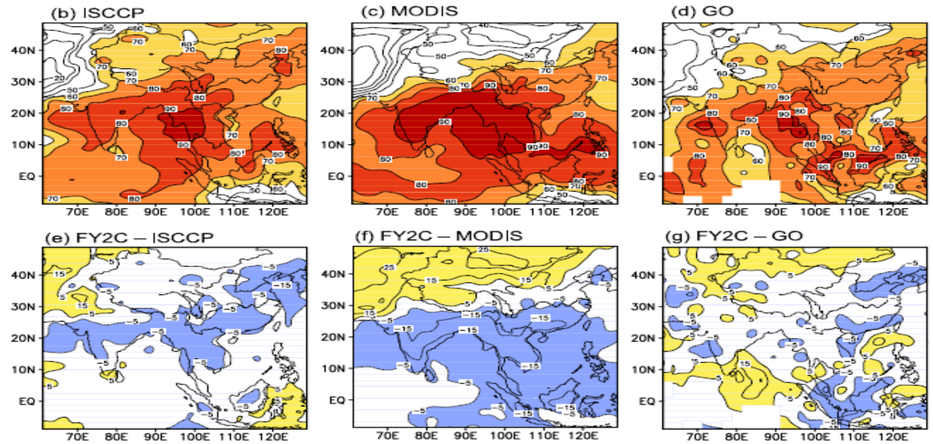
	ISCCP	MODIS	Ground Observation
FY-2C	0.90	0.82	0.56
ISCCP	–	0.90	0.72
MODIS	–	–	0.74



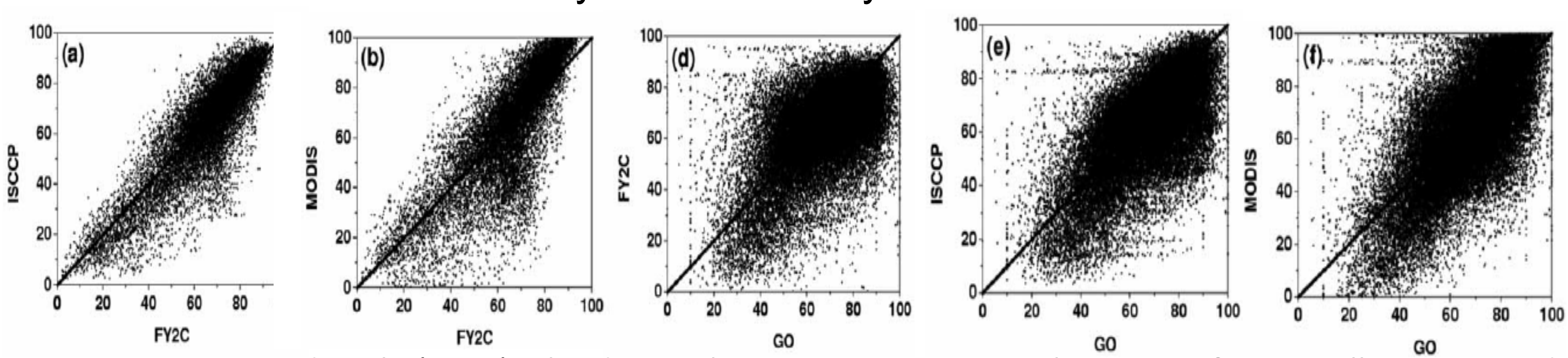
Summer(Jun-July-August)





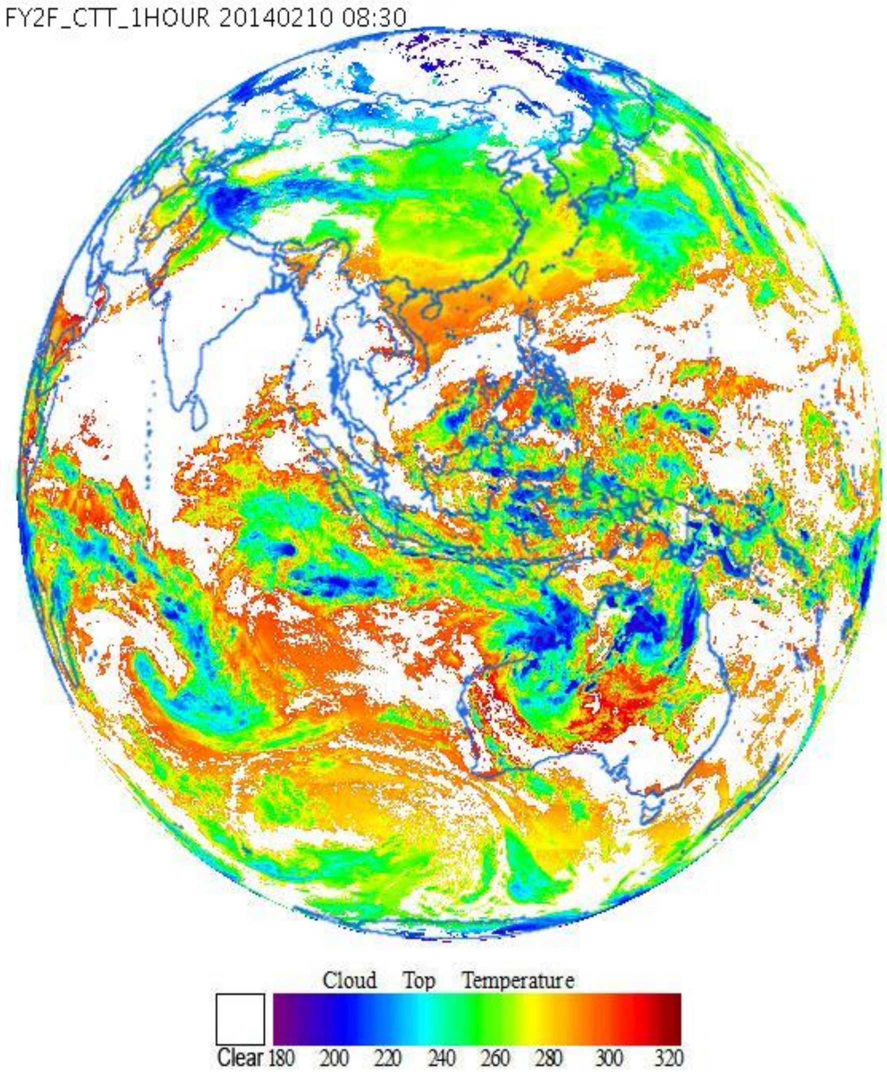


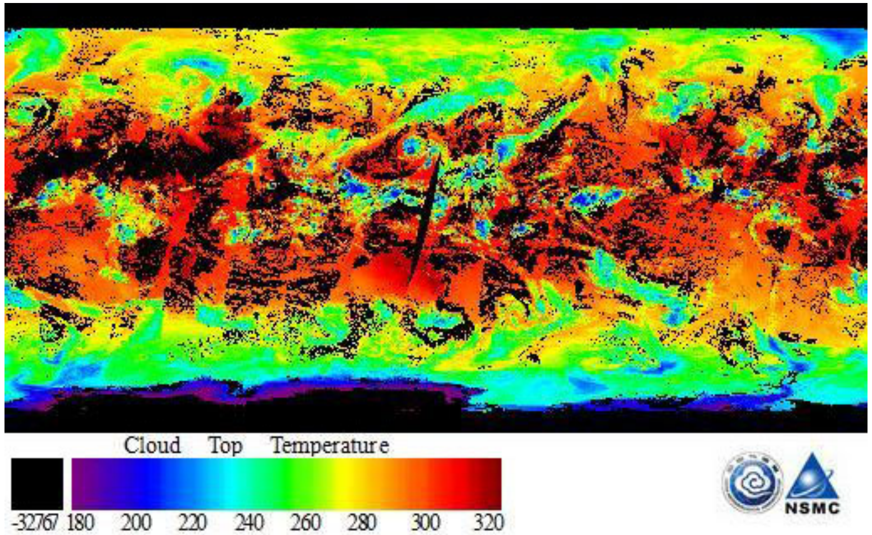
Scatterplots of mean monthly cloudiness July 2005 to June 2007

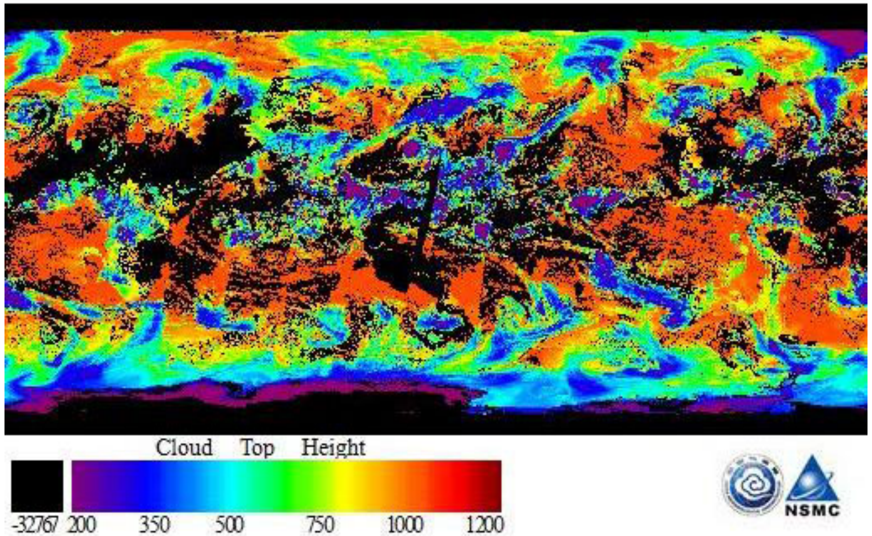


Jin, X., T. Wu, L. Li, and C. Shi (2009), Cloudiness characteristics over Southeast Asia from satellite FY-2C and their comparison to three other cloud data sets, J. Geophys. Res., 114, D17207, doi:10.1029/2008JD011422.

FY2 VISSR cloud top temperature







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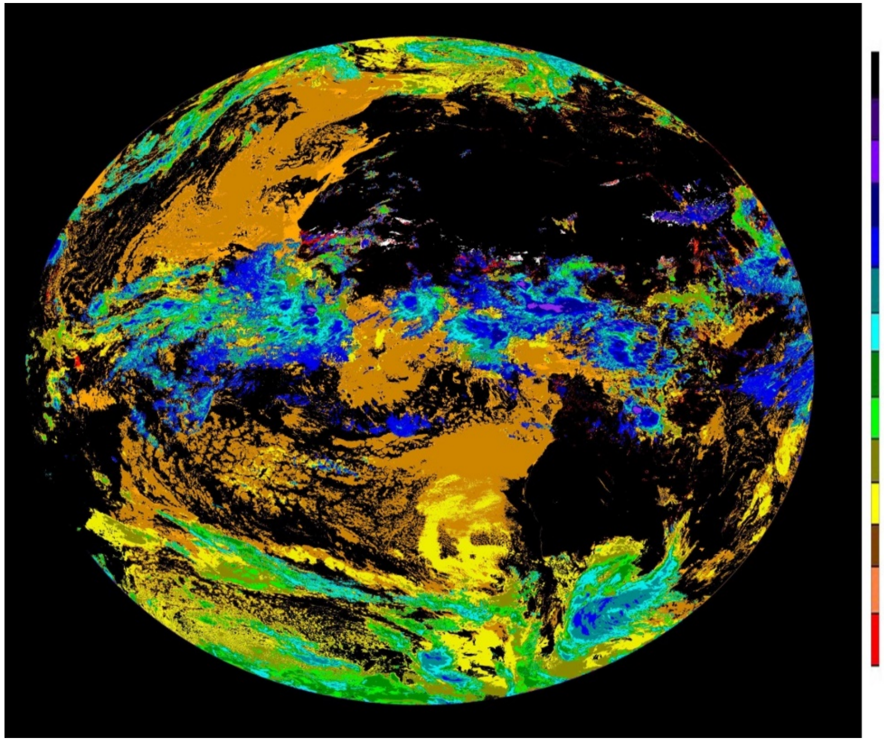
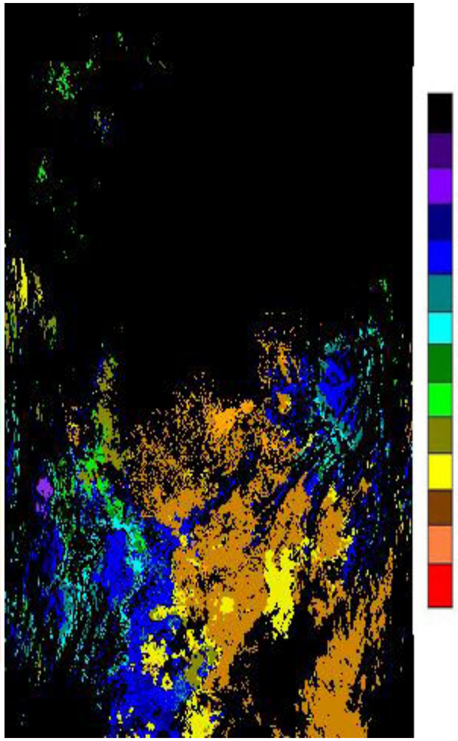
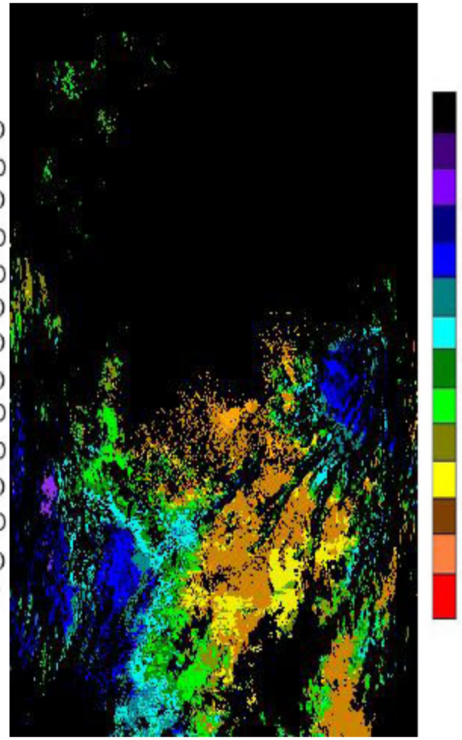
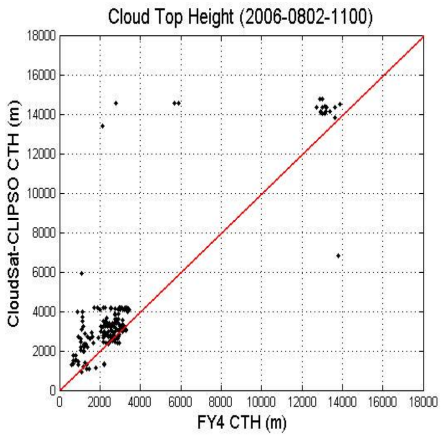
FY4/AGRI cloud top temperature validation

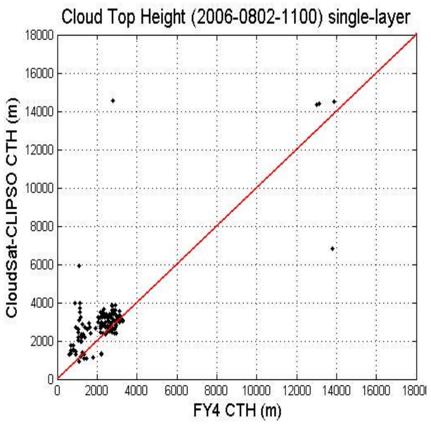
11,12,13.5

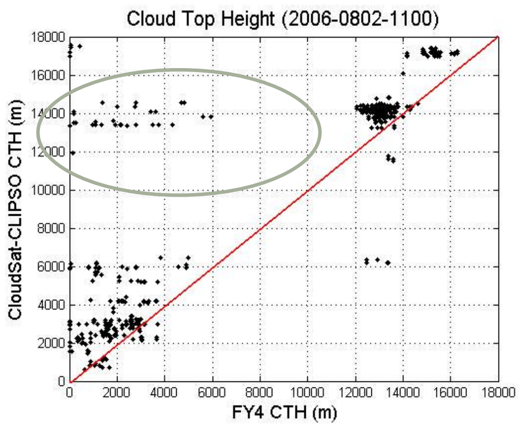


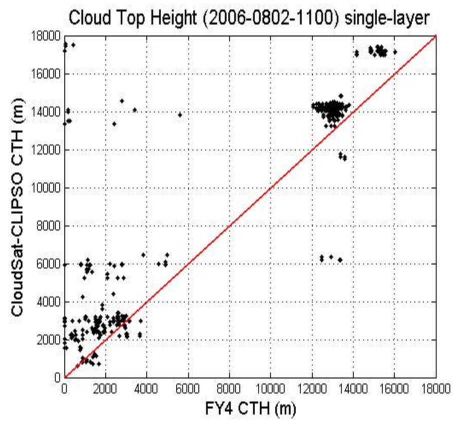










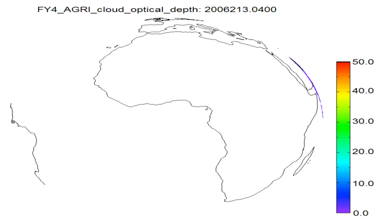


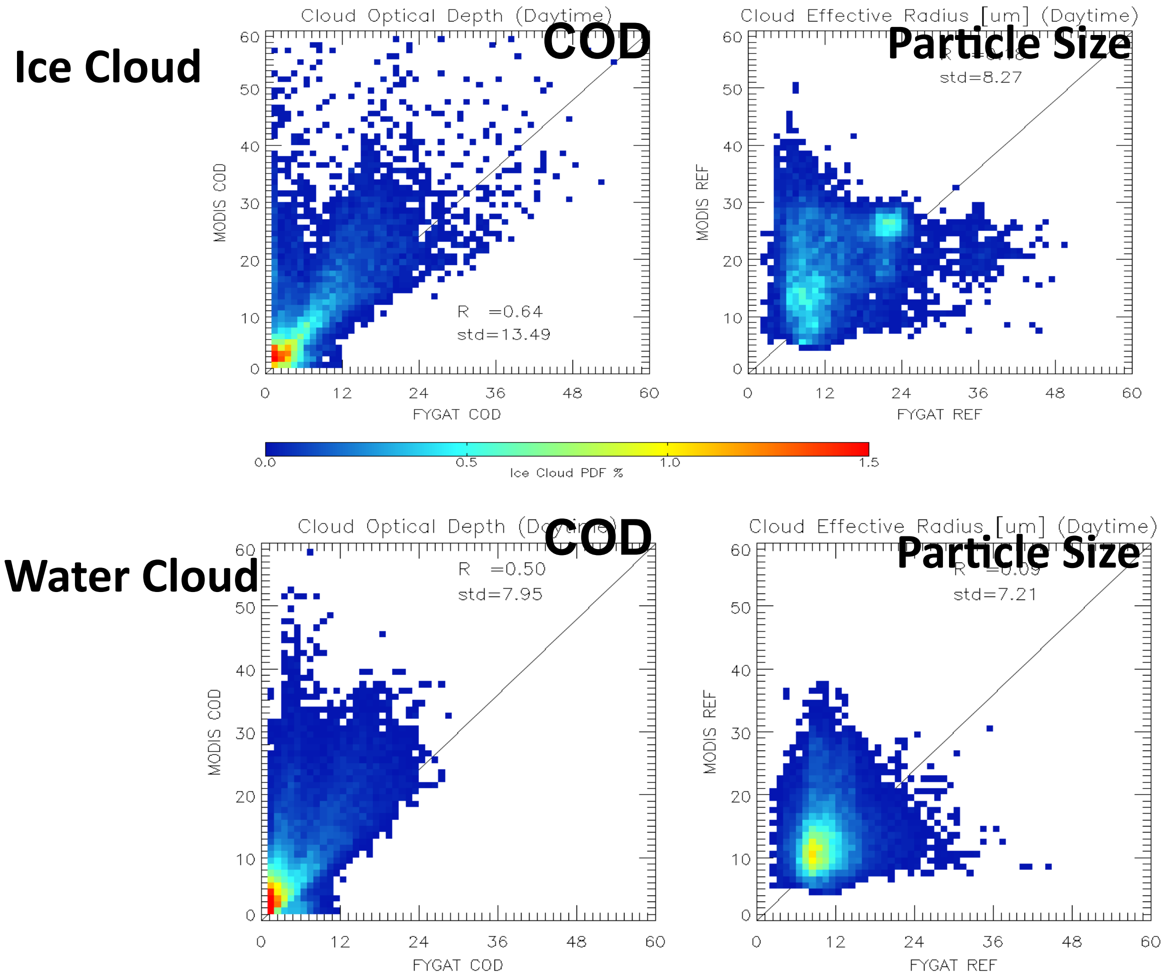
Clousat cloudtop products from 2B-CLDCLASS-LIDAR

FY4/AGRI Cloud Optical and Microphysical Properties (COMP)

Channel	Band (μm)	Spatial Resolution (Km)	Detection Sensitivity		Main Application	
Visible & Near-Infrared	0.45~0.49	1	S/N≥	70(ρ=100%)	Aerosol	
	0.55~0.75	0.5~1		200(ρ=100%),5 (ρ=1%)@0.5Km	Fog,Clound	
	0.75~0.90	1			Vegetation	DCOMP
Short-wave Infrared	1.36~1.39	2	S/N≥	200 (ρ=100%) 5 (ρ=1%)	Cirrus	
	1.58~1.64	2			Cloud,Snow	
	2.1~2.35	2~4			Cirrus,Aerosol	DCOMP
Mid-wave Infrared	3.5~4.0(high)	2	NEΔT≤0.7K(300K)		Fire	
	3.5~4.0(low)	4	NEΔT≤0.2K(300K)		Land surface	NCOMP
Water Vapor	5.8~6.7	4	NEΔT≤0.3K(260K)		WV	
	6.9~7.3	4	NEΔT≤0.3K(260K)		WV	
Long-wave Infrared	8.0~9.0	4	NEΔT=0.2K(300K)		WV,Clound	NCOMP
	10.3~11.3	4	NEΔT=0.2K(300K)		SST	NCOMP
	11.5~12.5	4	NEΔT=0.2K(300K)		SST	NCOMP
	13.2~13.8	4	NEΔT=0.5K(300K)		Clound,WV	

FY4/AGRI DCOMP Result &Validation





Comparison with MODIS products :

1. The correlation coefficient of COD is about 0.55, and much better than CPS(0.10) ;
2. The correlation of ice cloud is better than water cloud;
3. MODIS has mostly bigger values than DCOMP;

PDF Comparison of COD (left) and CPS (Right) in 2006-8-1 derived from MODIS (MYD06) products and from DCOMP algorithm.

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FY4/AGRI NCOMP Result &Validation

Channel used:

8.5 µm,11 µm,12 µm

Algorithmic dependencies :

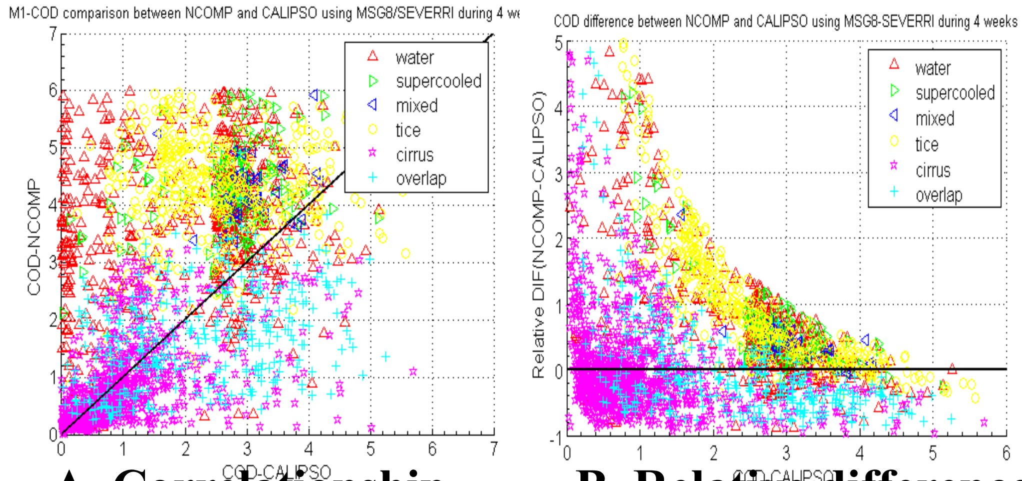
Cloud Type, Cloud Top Temp/Pres

Products generated:

COD, CPS, LWP/ IWP

Ref (Langley):GOES-R+CERES

Method: Simultaneously Nadir Observation with CALIPSO Lidar Product (thin cloud with COD 1~5)



A. Correlationship **B. Relative differences**

Comparison of matched NCOMP and CALIPSO COD using 4-weeks SEVIRI data with FY4 Cloud Type indicated by color.

Cirrus points, despite generally having the lowest CODs, have the best agreement with CALIPSO. The overlap clouds also have relatively low differences。 NCOMP results are bigger than CALIPSO products

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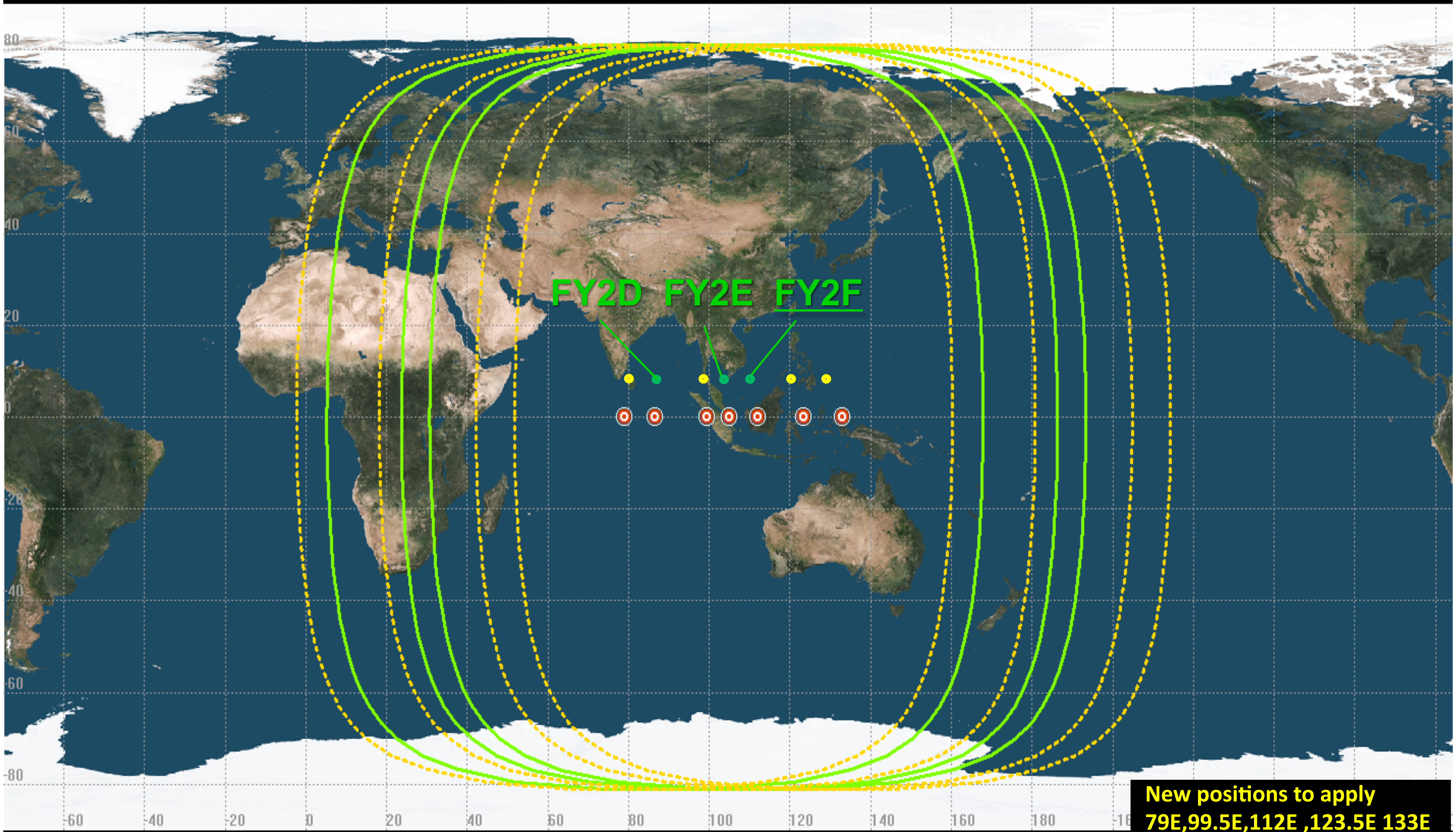
Attempts to derive cloud top height using two geosynchronous satellite: Motivation

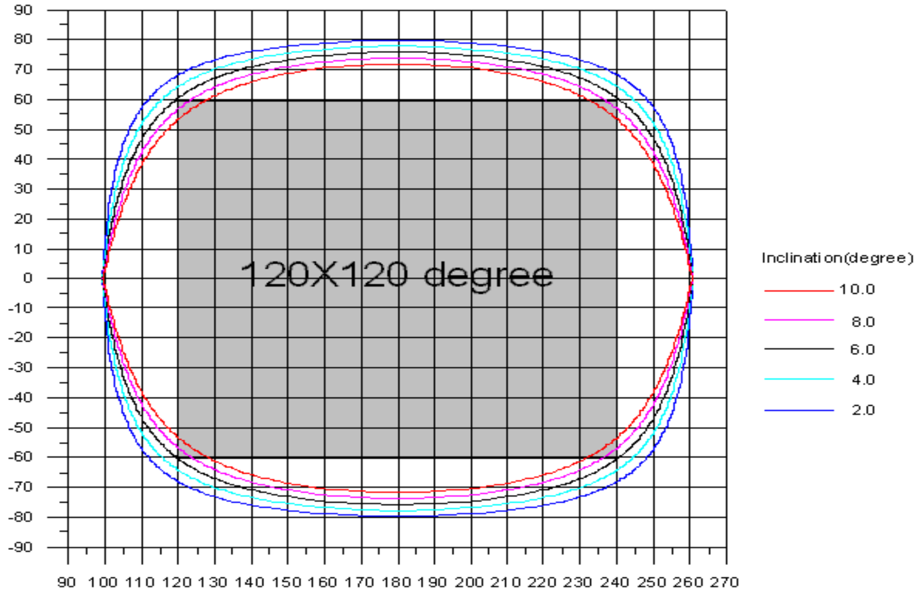


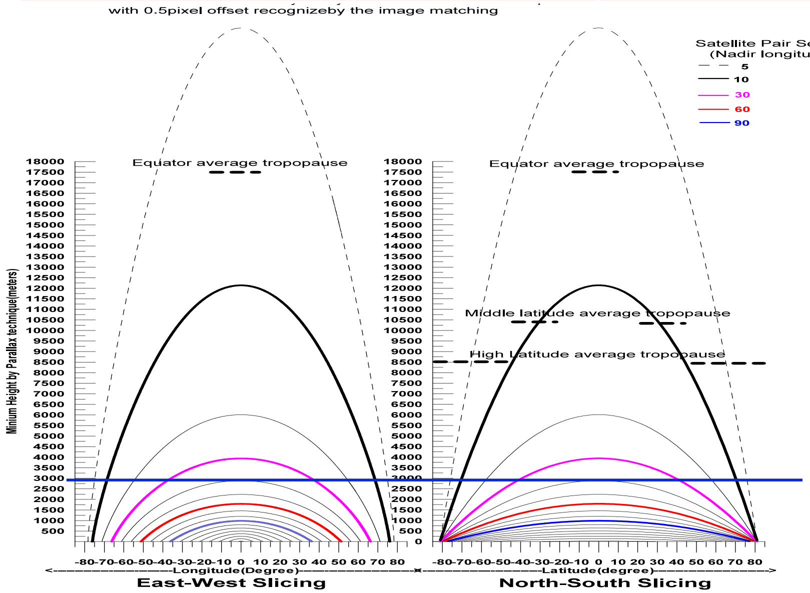
Heritage operational positions from FY-2 86.5E,105E and 112.0E

Revision 201310

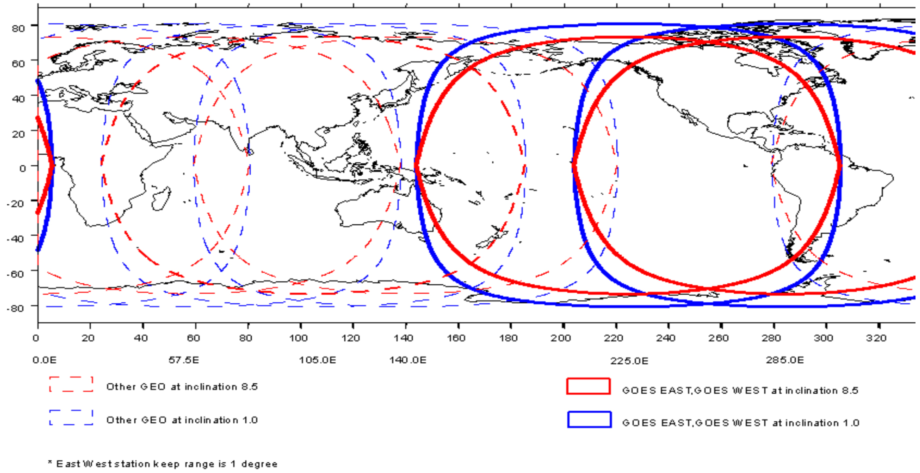
Attempts to derive cloud top height using two geosynchronous satellite: Bias analysis

SAT_ID	SSP	westward distance
Meteosat	3.4 W	59.6
(IODC)	57.5E	59.9
FY2D	86.5E	29
FY2C	105.0E	20
MTSAT	140.0E	35
GOES	135.0W	85
GOES	**75.0W**	**60**



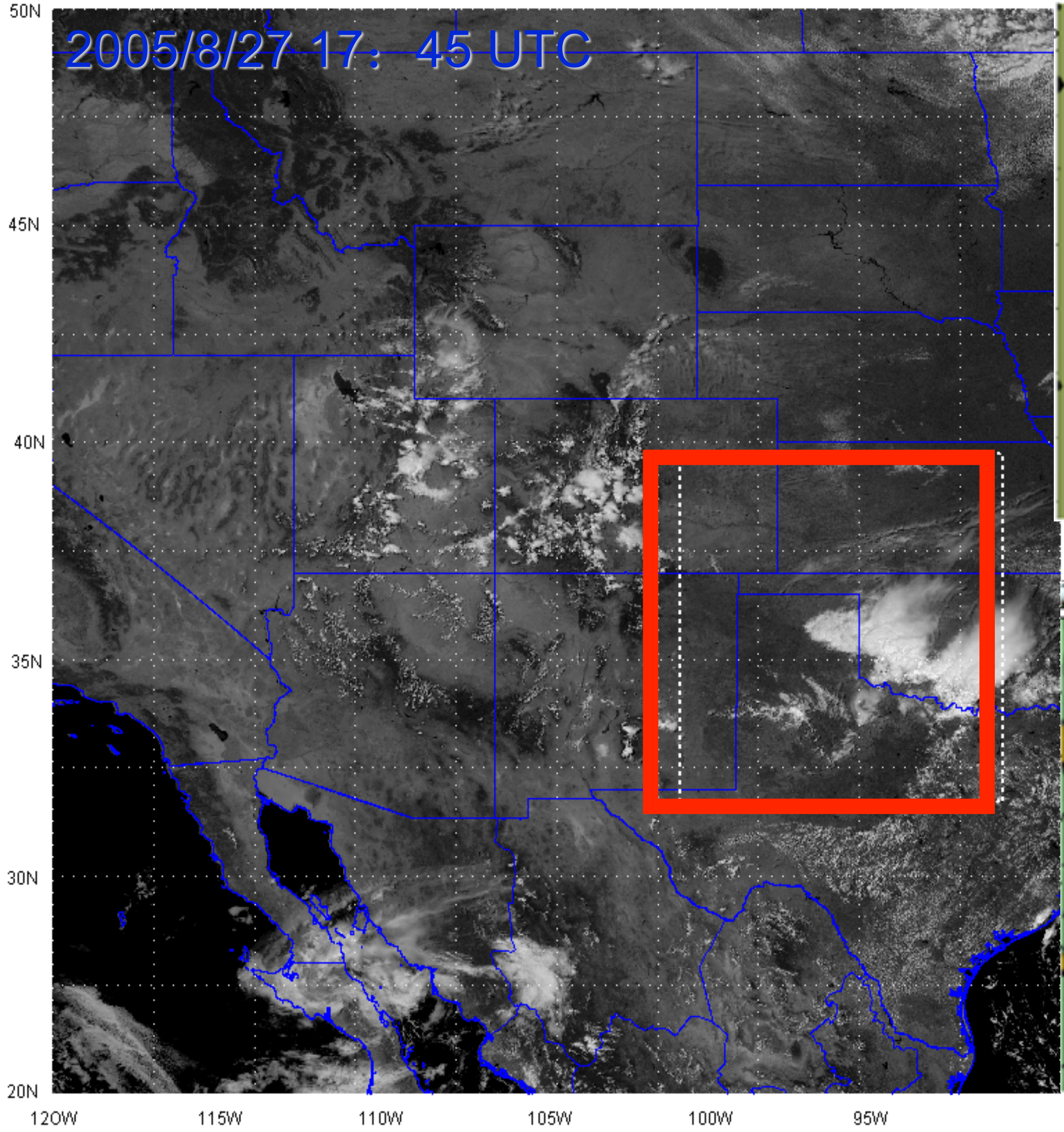


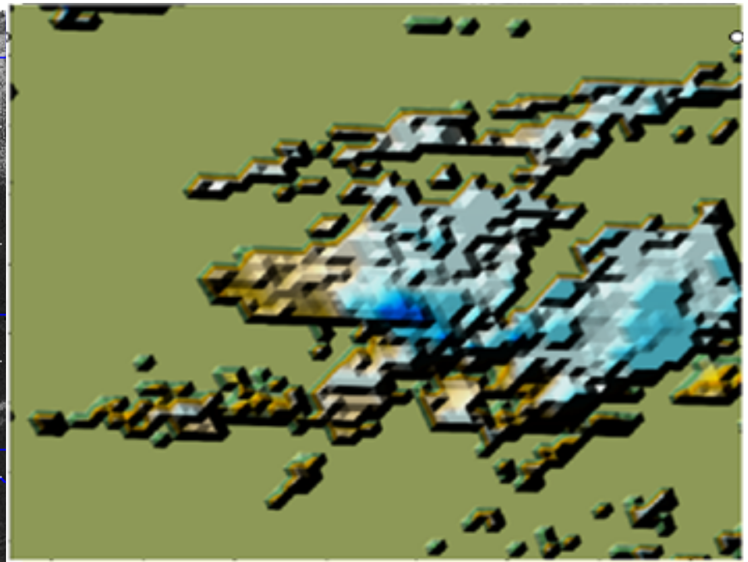
Cloud height >1.6Km detectable



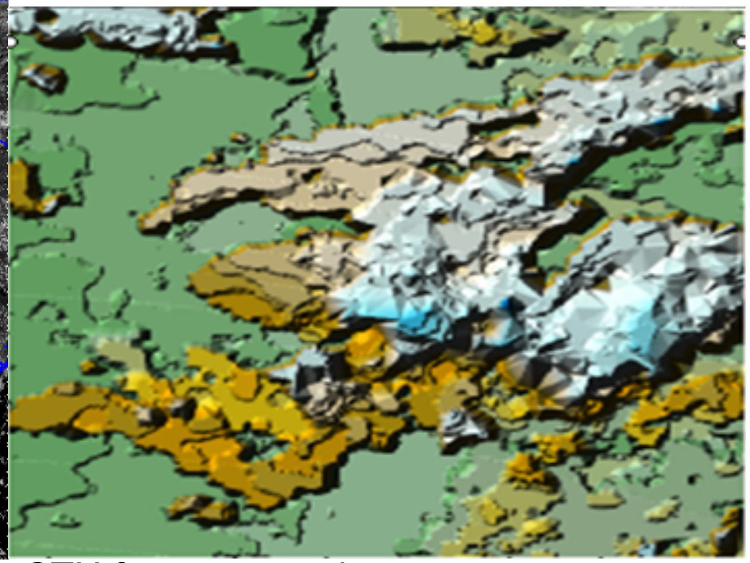
GEOMETRIC CLOUD TOP HEIGHT ASSIGNMENT BY GEOSYNCHRONOUS METEOROLOGICAL SATELLITE IMAGES,Feng Lu,Jianmin Xu, W. Paul Menzel,Christopher S. Velden, IGARSS 2009

Attempts to derive cloud top height using two geosynchronous satellite: Case study



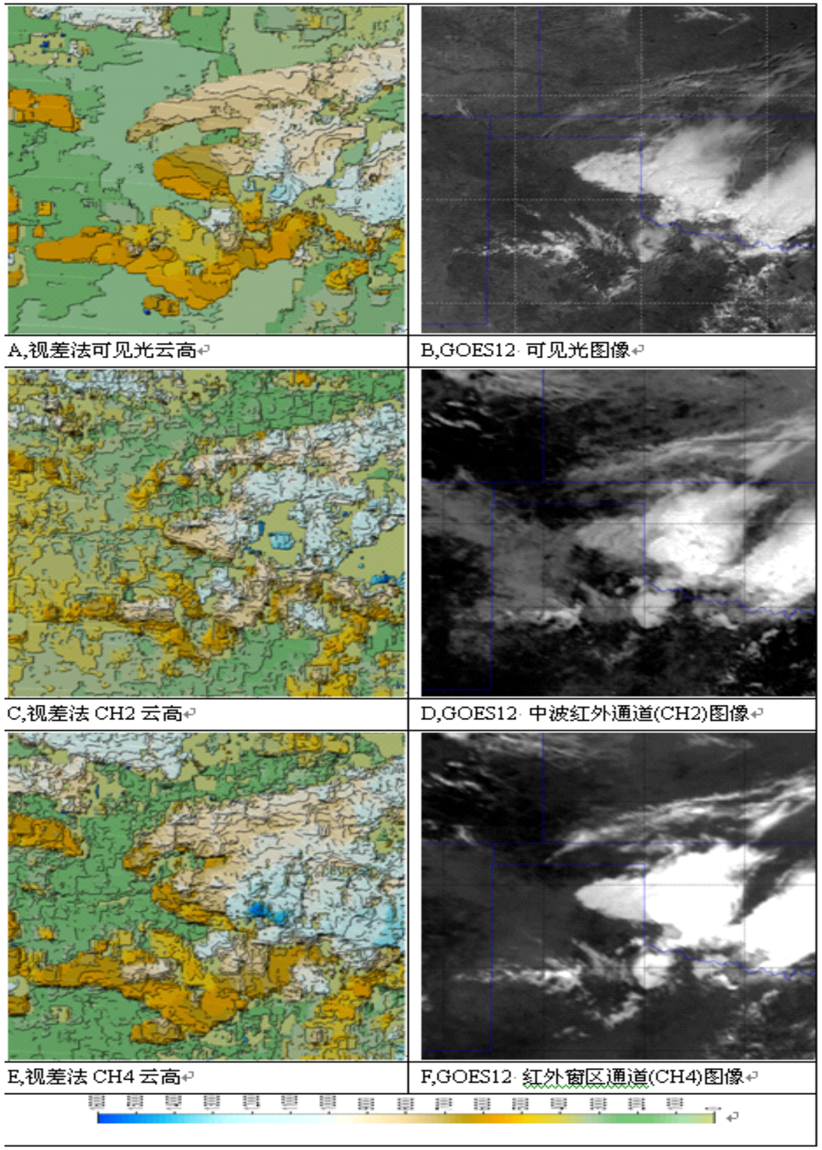


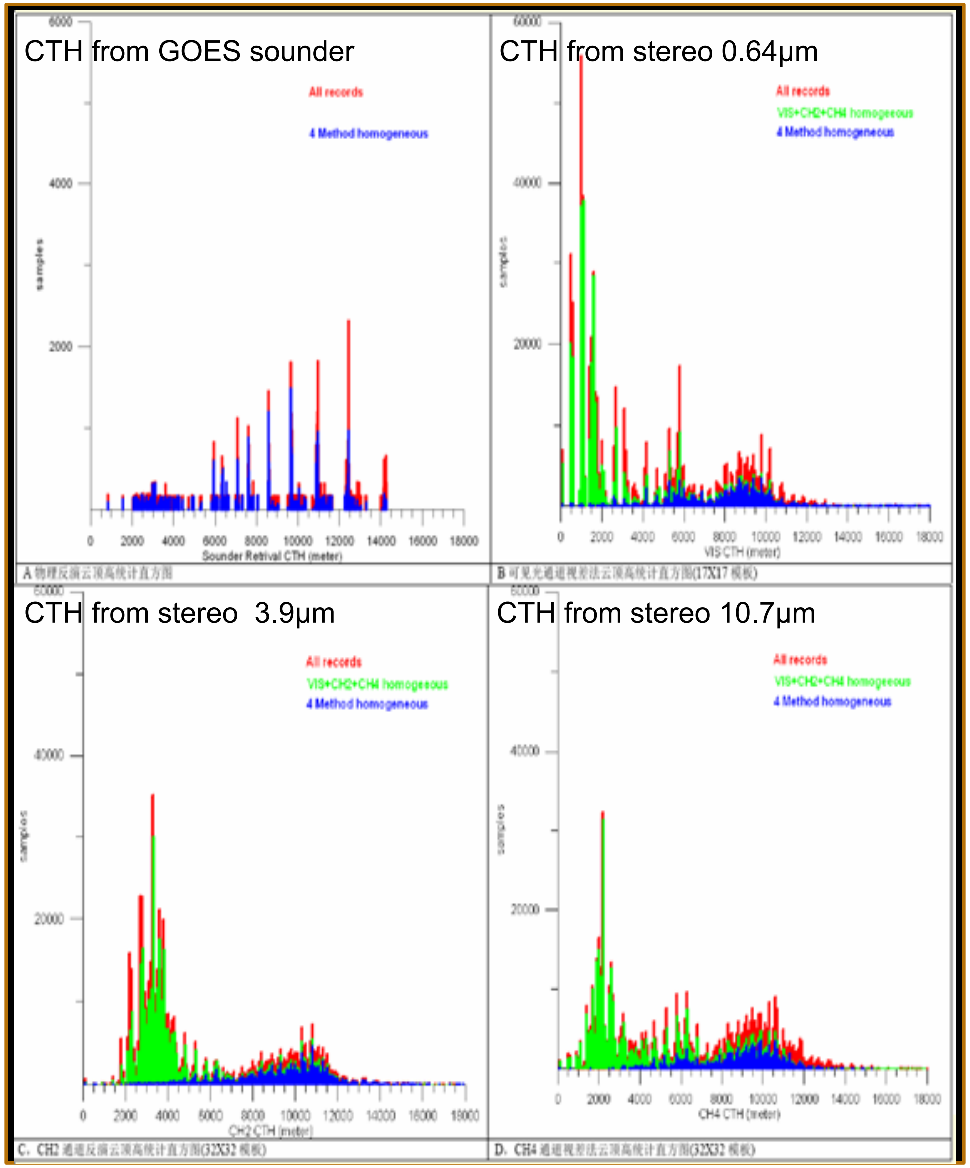
CTH from GOES sounding



CTH from stereo view

Comparisons: Stereo CTH vs Current products





Blue :homogenous records for 4 dataset RED: All records; Green: :homogenous records for stereo CTH,

VIS stereo CTH: good for low cloud

IR stereo CTH: good for high cloud

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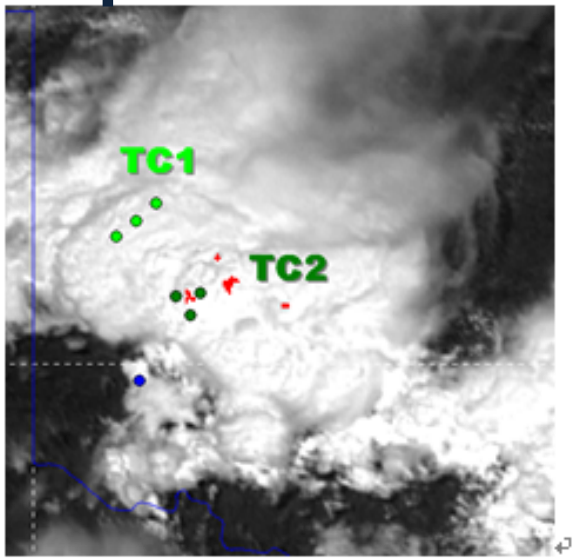
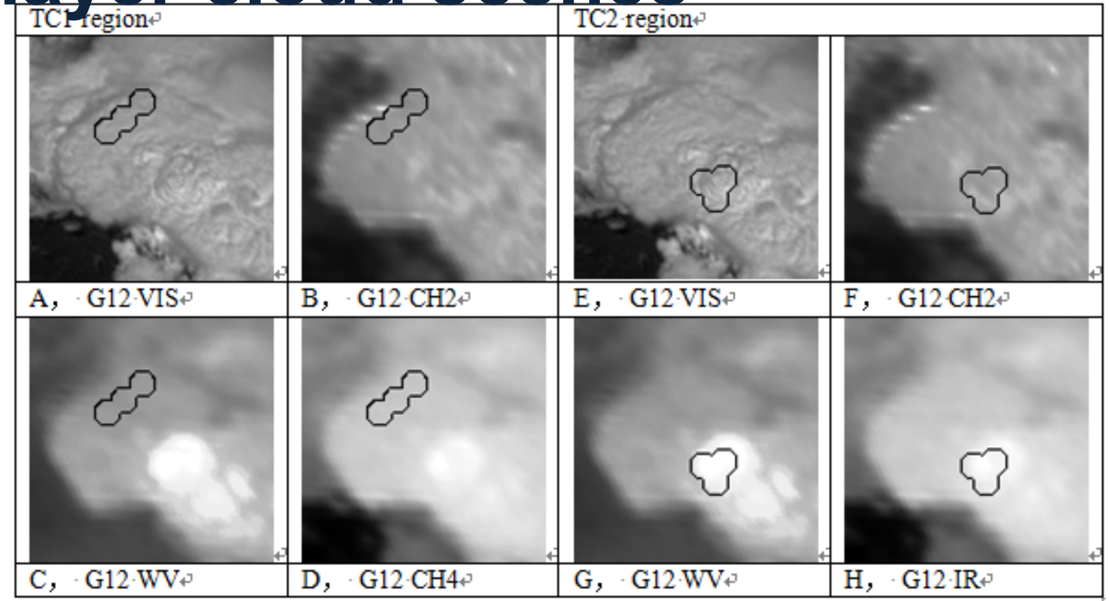
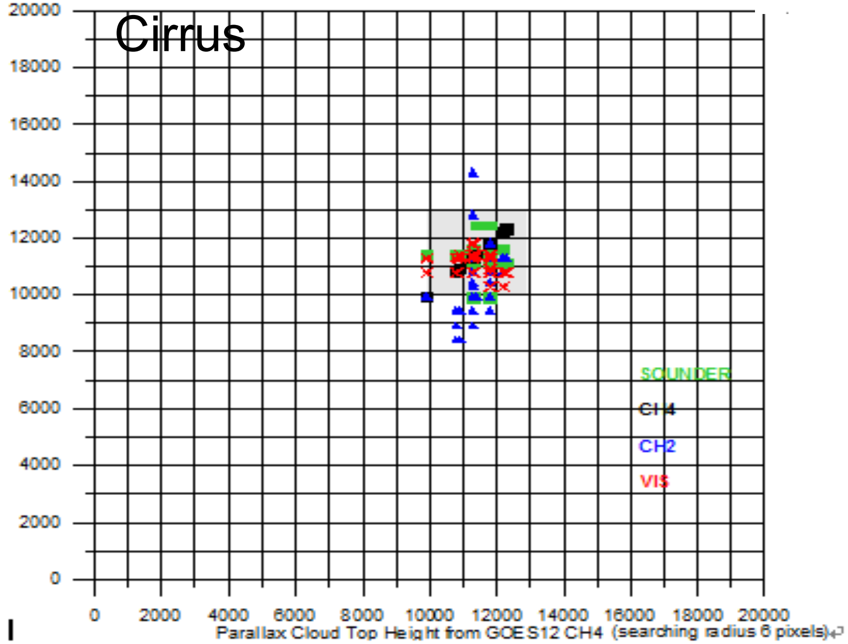
Comparisons: Multilayer cloud scenes



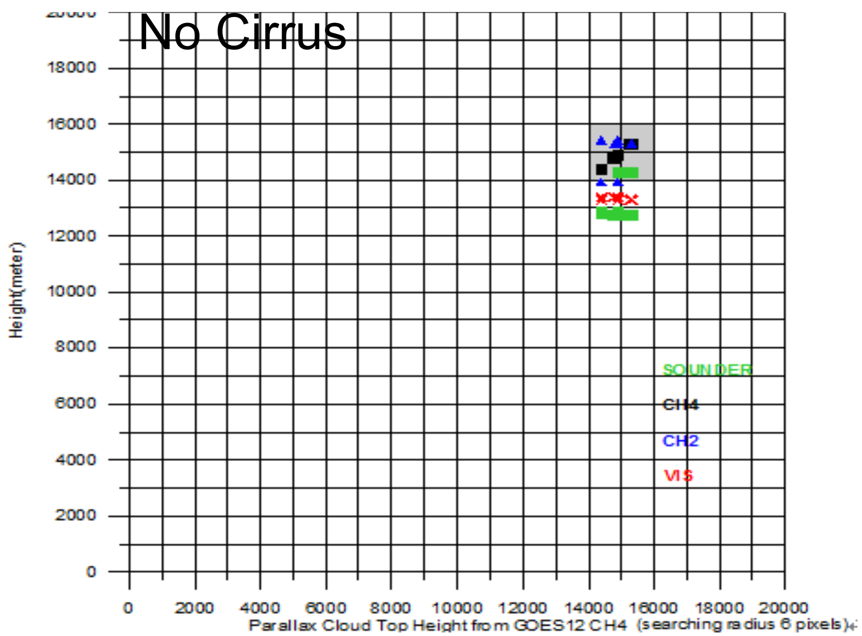
A,TC1,TC2 样本点分布



TC1/TC2 区域 GOES12 通道图像



A， TC1 区域



B， TC2 区域

CH2 3.9

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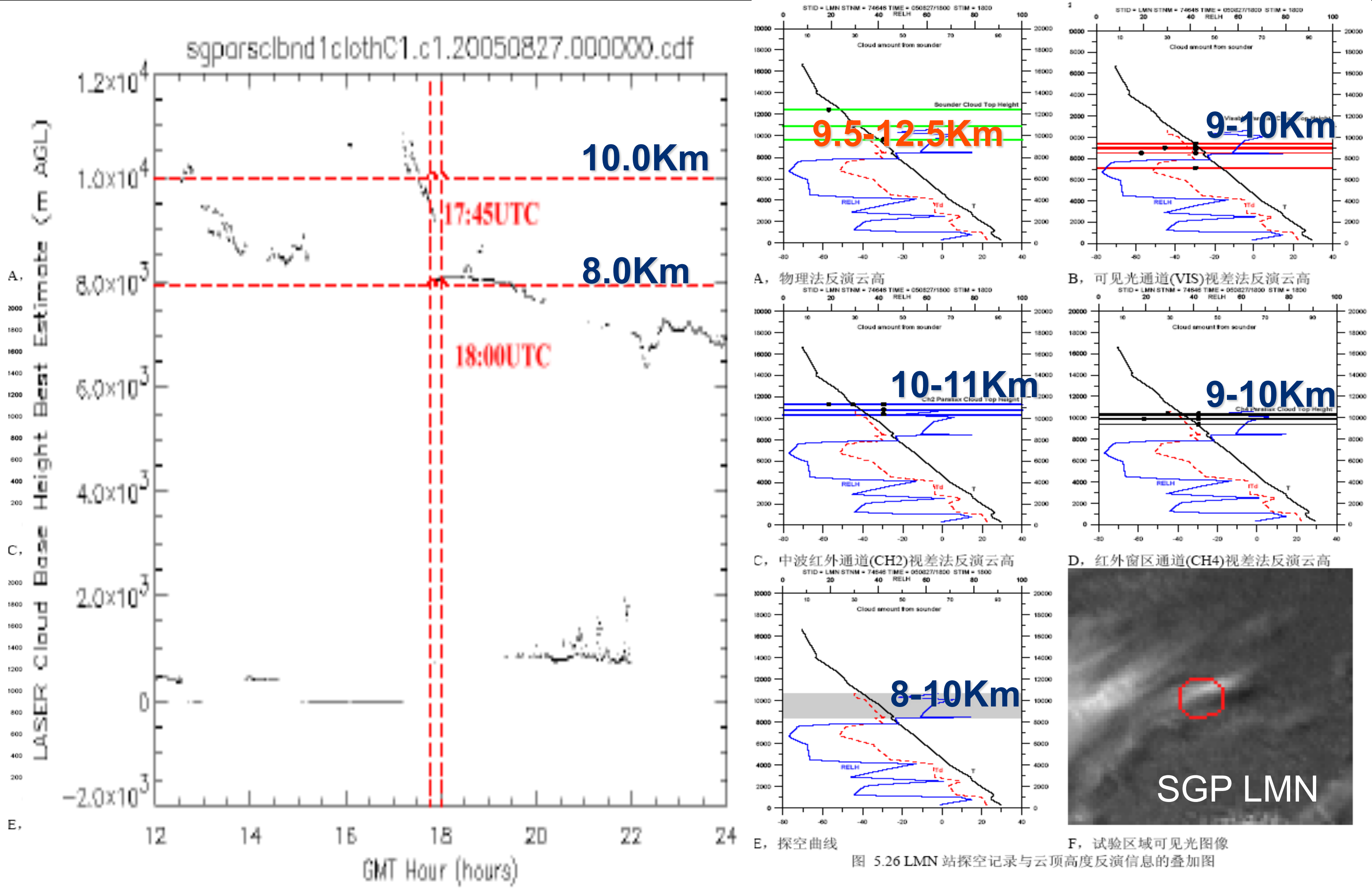
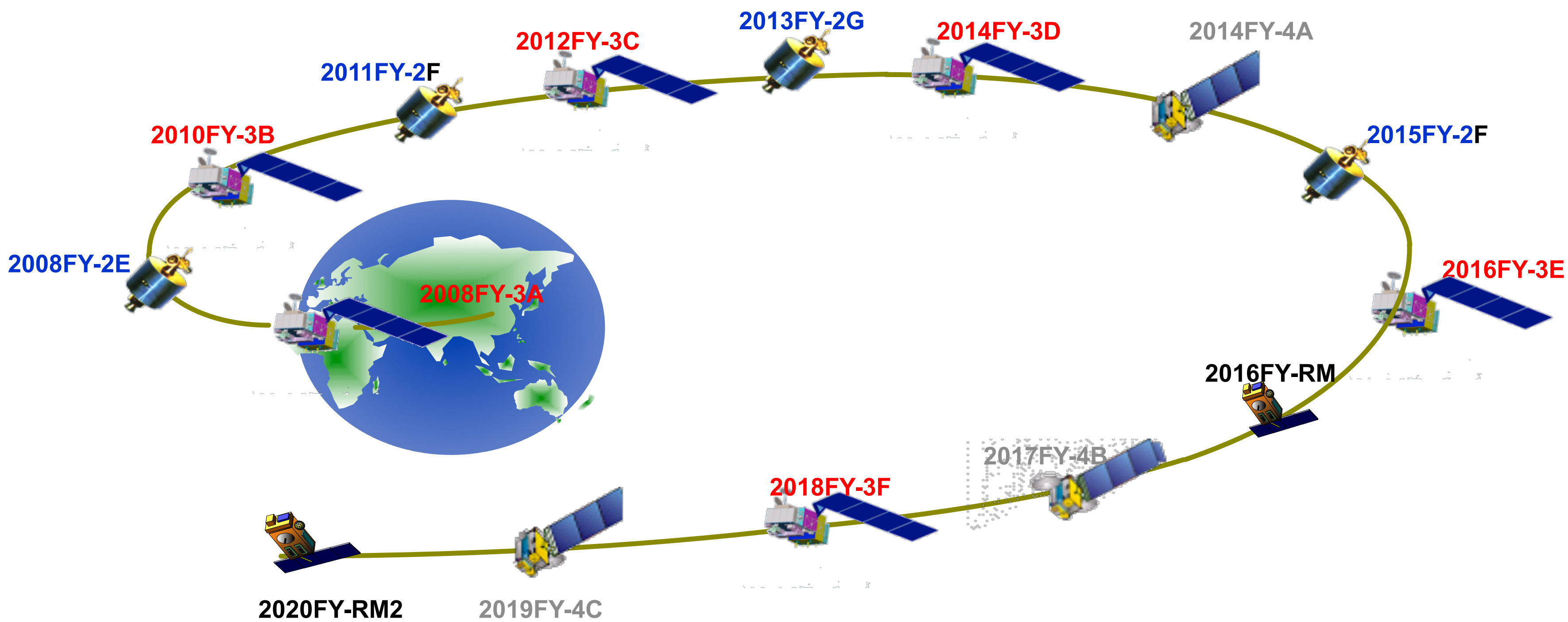
Comparisons :Thin Cirrus Cloud scenes(20-40%)



Big difference between GOES Sounder and stereo CTH. Laser CBH is agree with sounding profile agrees well with stereoCTH.

- Satellite Programs & Major Payloads
- Cloud Products and Potential applications
- Forward Look



1)Current CMA cloud products validation based on ground observations, CMA is planning to develop an operational cloud product validation system based on inter comparison with other satellite data source .

2) The FY-4 will provide Interferometric Infrared Sounder in 2016, it will provide new data for Cloud retrieval with higher temporal resolution.

3)CMA is interested in Cloud Radar, and planning make an prototype instrument（94G+220G?） and make field observations.

Summary

CMA/NSMC focuses on operational satellite meteorological applications and capacity building. In-depth research and demonstration efforts are encouraged for the applications of new data in weather analysis, NWP, etc., including Cloud retrieval and validation.

CMA will keep its commitment to open data policy for Fengyun data. Engagement of regional and global users in the application of Fengyun data are welcome.

International partnerships are essential. CREW is a very important value added benefit to Fengyun cloud product and validation.

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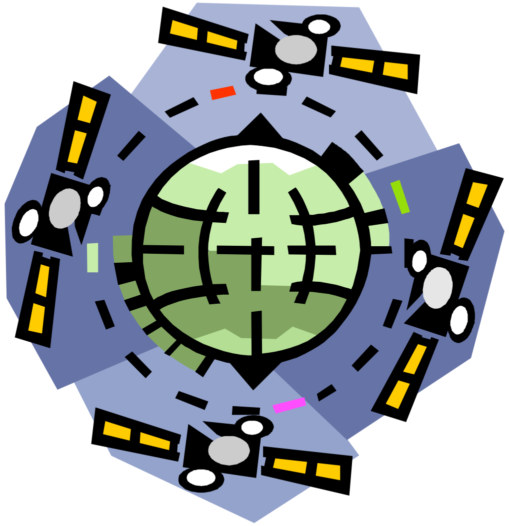
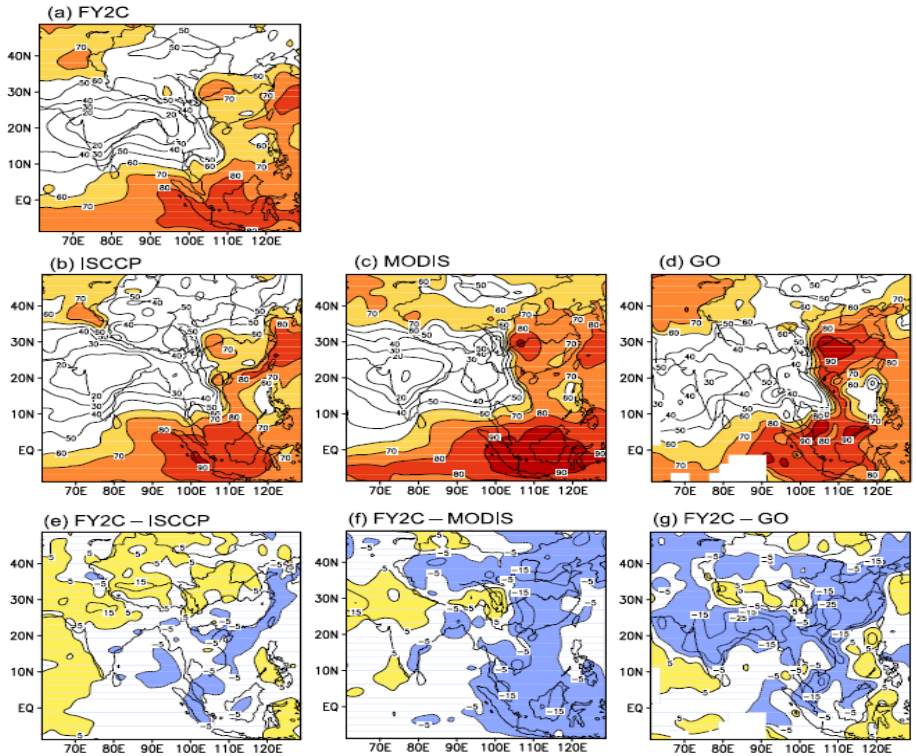
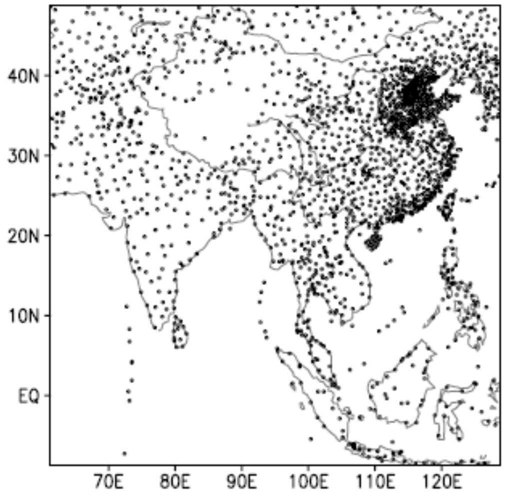


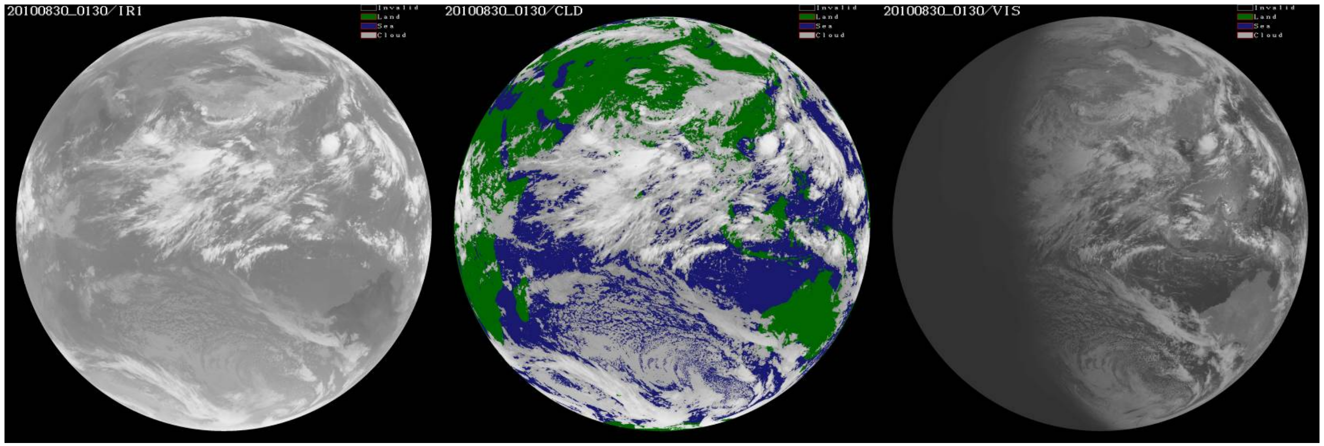
Thank you

2005.7~2007.6,60°E~130°E, 10°S~50°N

	200701 (754 stations)			200706 (758 stations)		
	Pixels	match	准确率	Pixels	match	准确率
Clear(Day)	5003	3923	0. 7841	526	437	0. 8308
黄/黎晴空	1383	956	0. 6913	122	92	0. 7541
Clear(Night)	10602	7380	0. 6961	3085	2205	0. 7147
Clear	16988	12259	0. 7216	3733	2734	0. 7324
Cloud(Day)	19995	18507	0. 9256	32585	30461	0. 9348
黄/黎全云	13410	11501	0. 8576	5457	5083	0. 9315
Cloud(night)	29991	24585	0. 8197	29598	27069	0. 9146
Cloud	63396	54593	0. 8611	67640	62613	0. 9257
总　　计	80384	66852	0. 8317	71373	65347	0. 9156
两月总计	**151757**	**132199**	**0.8711**			







Jin, X., T. Wu, L. Li, and C. Shi (2009), Cloudiness characteristics over Southeast Asia from satellite FY-2C and their comparison to three other cloud data sets, J. Geophys. Res., 114, D17207, doi:10.1029/2008JD011422.

FengYun LEO. Satellites: