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Evaluation of Satellite and Reanalysis Products of Downward Surface Solar Radiation over East Asia

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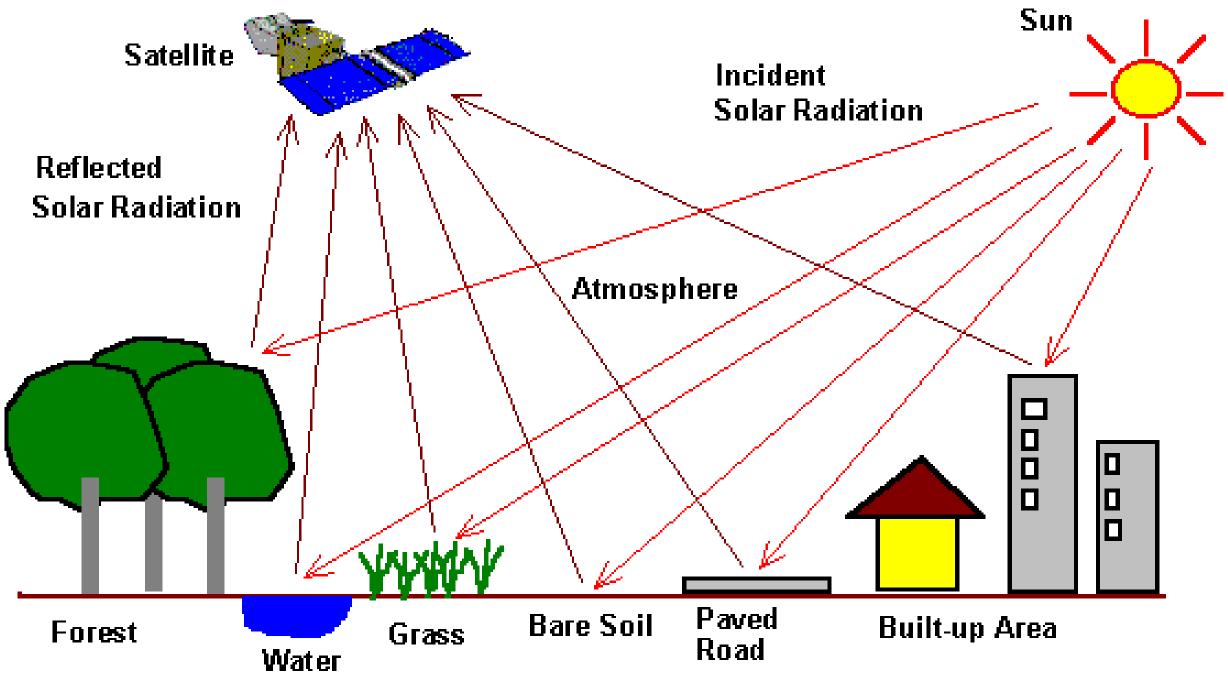
Outline

1. **Background**
2. Data and methods
3. Evaluation of satellite and reanalysis products
4. Spatial and seasonal variations of DSSR
5. Discussion and conclusion

1. Background

- **Downdard Surface Solar Radiation (DSSR) plays an important role in the energy and water cycles in the Earth climate system.**



- **Recently, several global products of surface solar radiation based on *satellite observations* have become available:**

ISCCP-FD, GEWEX-SRB, UMD-SRB, CERES, FLASHFLux, GMS5, GOES, …

- **Surface solar radiation data sets with higher temporal-spatial resolution are needed, especially over East Asia.**

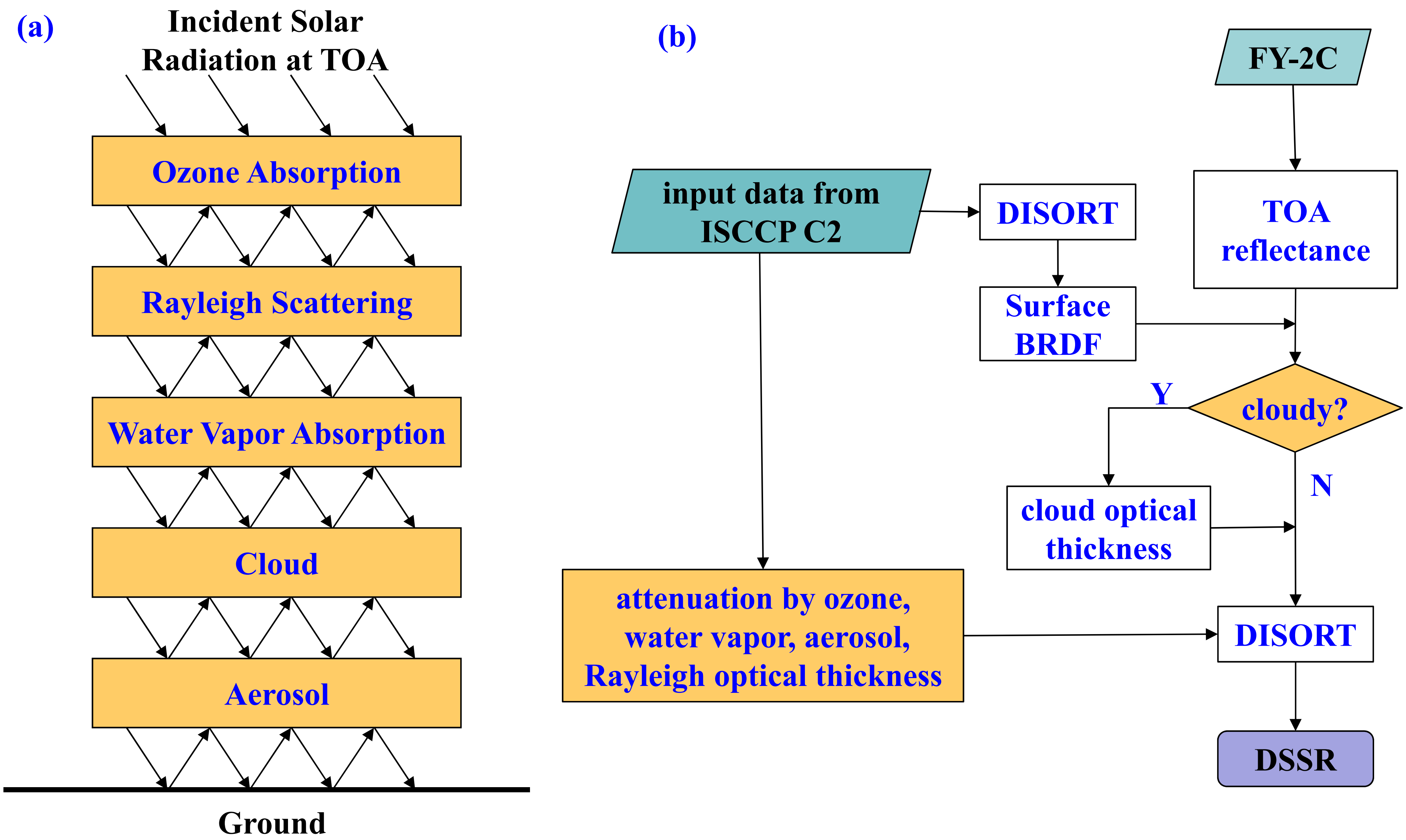
Fengyun Satellite (FY-2C)

- FY-2C, launched on 19 October 2004, was the first operational satellite of the FY-2 series [*Jin et al.*, 2009].
- Its geostationary orbit is located over the equator at **105°E**.
- The major payload in FY-2C is a **five-channel visible/infrared spin scan radiometer** (***VISSR***) for detecting visible, infrared, and water vapor images of the Earth [*Xu et al.*, 2002; *Lu et al.*, 2008].

Channel	Spectral Band (μm)	Spatial Resolution (km)	FOV (μrad)	Dynamic Range (K)
VIS	0.55~0.90	1.25	0~98%	35
IR1	10.30~11.30	5.00	180~330 K	140
IR2	11.50~12.50	5.00	180~330 K	140
IR3	3.50~4.00	5.00	180~330 K	140
WV	6.30~7.60	5.00	180~280 K	140

① **Calculation of surface bidirectional reflectance distribution function (BRDF) under clear skies.**
② **Determination of the presence of cloud in pixels.**
③ **Retrieval of cloud optical thickness.**
④ **Calculation of DSSR under clear skies or cloudy.**

FY-2C DSSR



(a) Five main physical processes, and (b) the flowchart of the retrieval algorithm of DSSR from FY-2C satellite.

2. Data and methods

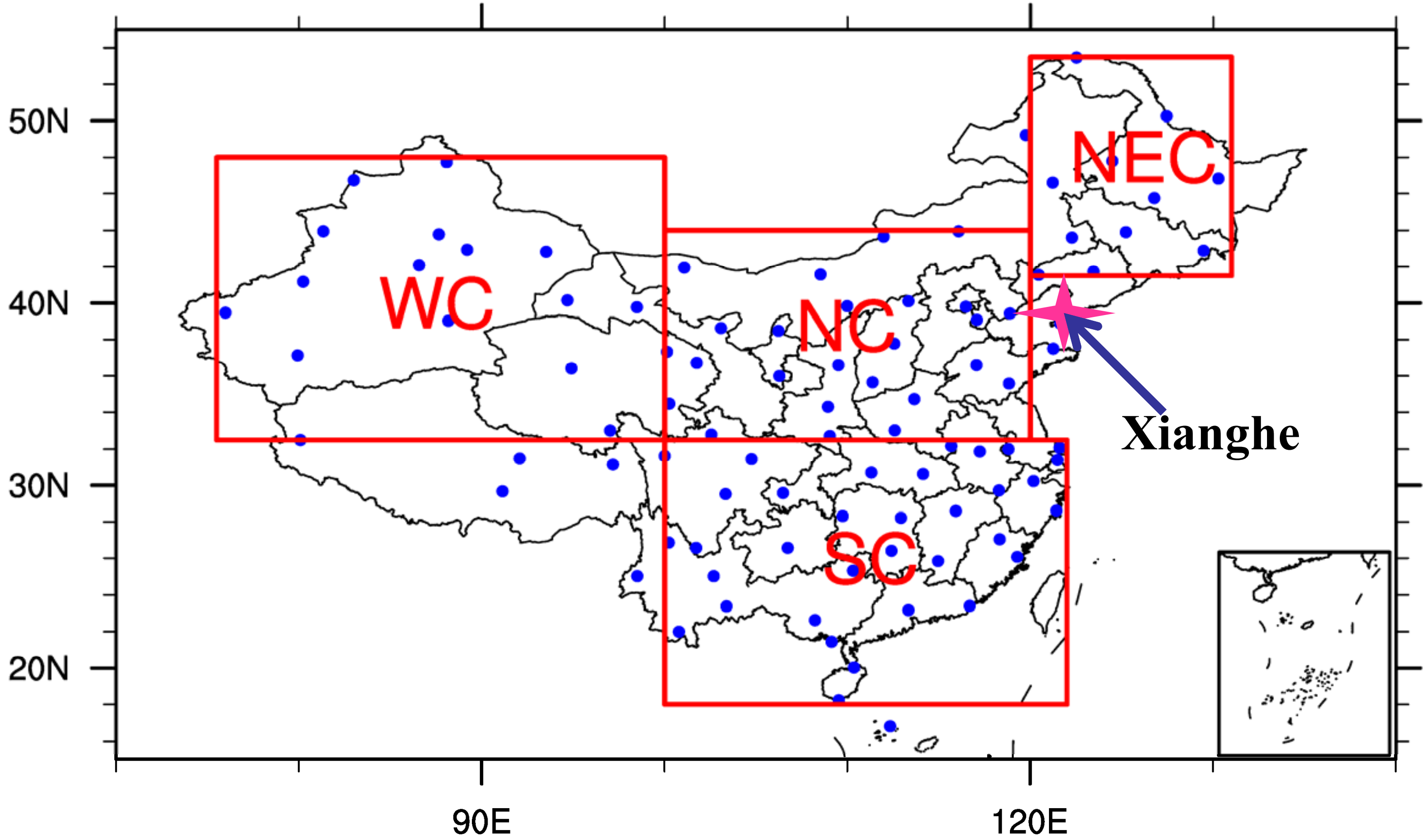
Information of DSSR Datasets

Products	Spatial Resolution	Temporal Resolution	Algorithm	Period
FLASHFlux	1°	hourly	Gupta et al. (2001)	Jul. 2006 – present
FY-2C	0.1°	hourly	Shi (2008)	Jun. 2005 – present
NCEP-DOE	T62	3 hourly	Kanamitsu et al. (2002)	1979 – present
ERA-Interim	1.5°	daily	Dee et al. (2011)	1989 - present

Used in this study: July 2006 – June 2009

Ground Observations

- **Xianghe (39.753°N, 116.961 °E): data have been quality controlled using the Baseline Surface Radiation Network (BSRN) quality control procedure** [*Xia et al.*, 2007; *Li et al.*, 2007].
- **122 stations from CMA; *94 sites* were used after disregarding some stations because of incomplete or poor-quality records in this study.**

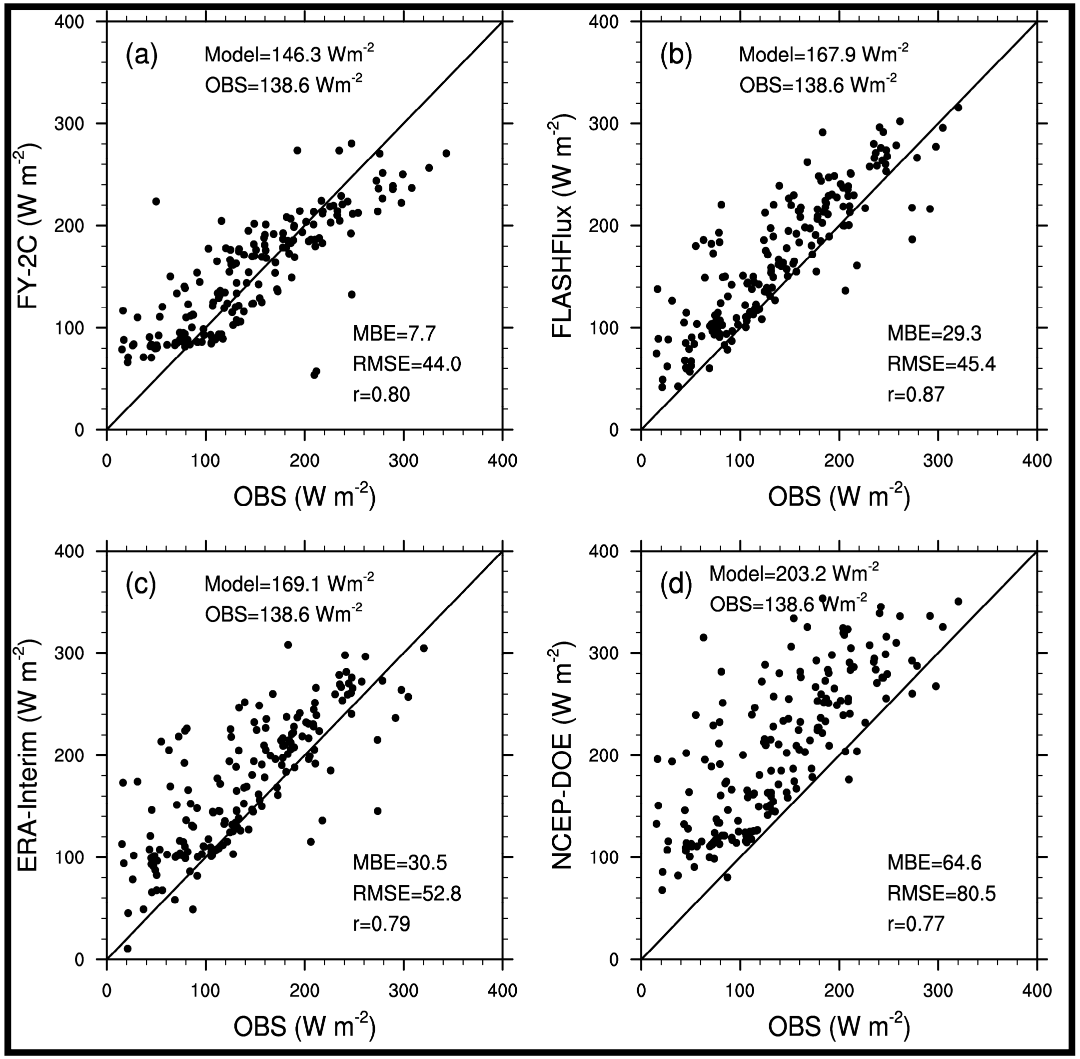


Evaluation Measures

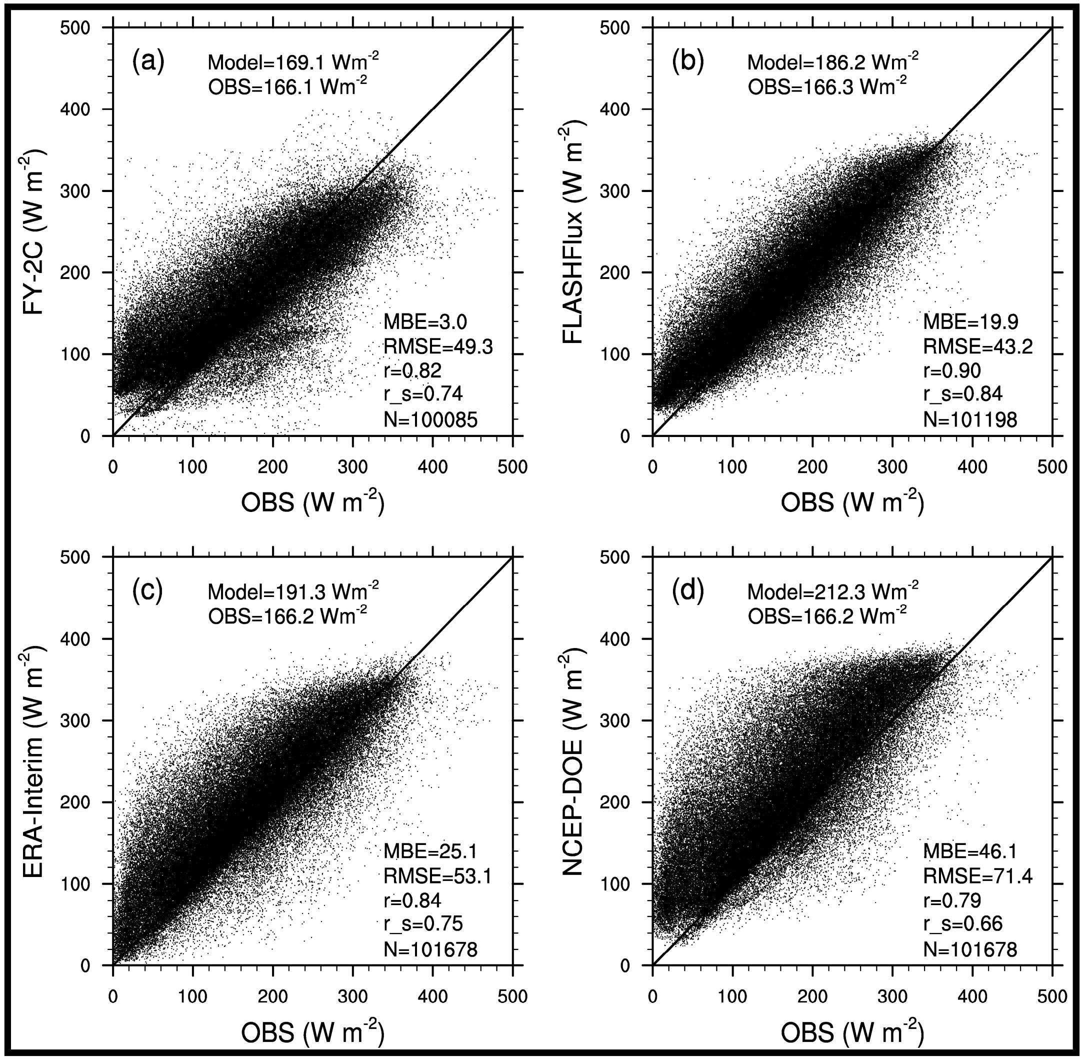
- ***Quality Control*: Outliers (outside the ±3 s.d. range) in the daily DSSR were removed in the analysis for all four DSSR products.**
- **Issues Related to Data Resolution.**
- **Performance measures against *OBS*: mean bias error (MBE), root mean square error (RMSE), the correlation coefficient (*r*), normalized standard deviation (NSD), and centered RMSE (cRMSE).**
- **Spatial and seasonal variations.**
- **Discuss the causes of discrepancies between the different DSSR products.**

3. Evaluation of satellite and reanalysis products

Xianghe Site **(Jul. 01 - Dec.31, 2006)**



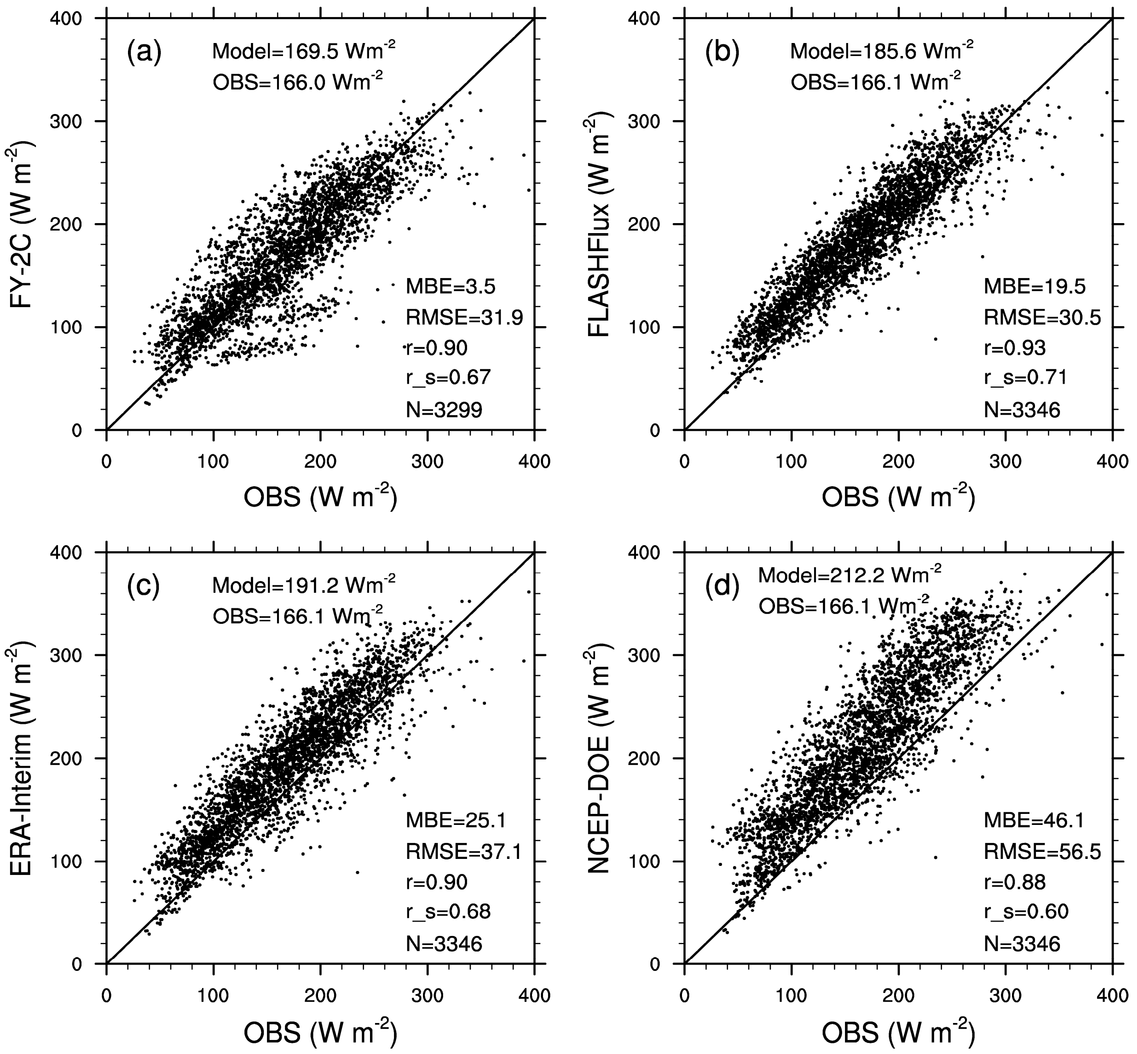
94 Sites From CMA **(Jul. 01 2006- Jun.30, 2009)**



Daily DSSR products

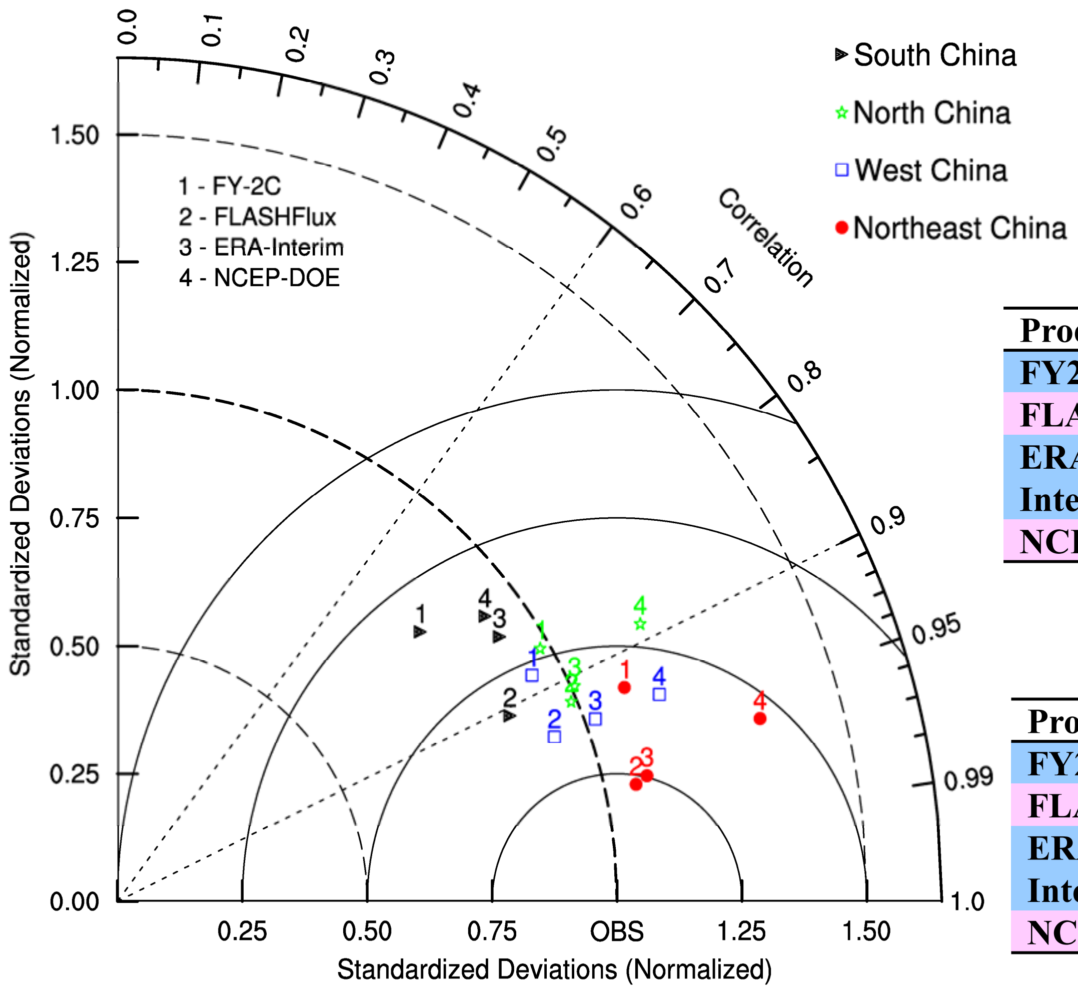
Jia et al., 2013, JGR-Atm.

Monthly DSSR



- **The FLASHFlux DSSR has the highest correlation coefficient (*r* = 0.93).**
- **FY-2C and ERA-Interim products have lower correlations with OBS (*r* = 0.90).**
- **The NCEP-DOE reanalysis compares relatively poorly with OBS, producing the lowest correlation coefficient (*r* = 0.88).**

Performances over different subregions



(a) MBE

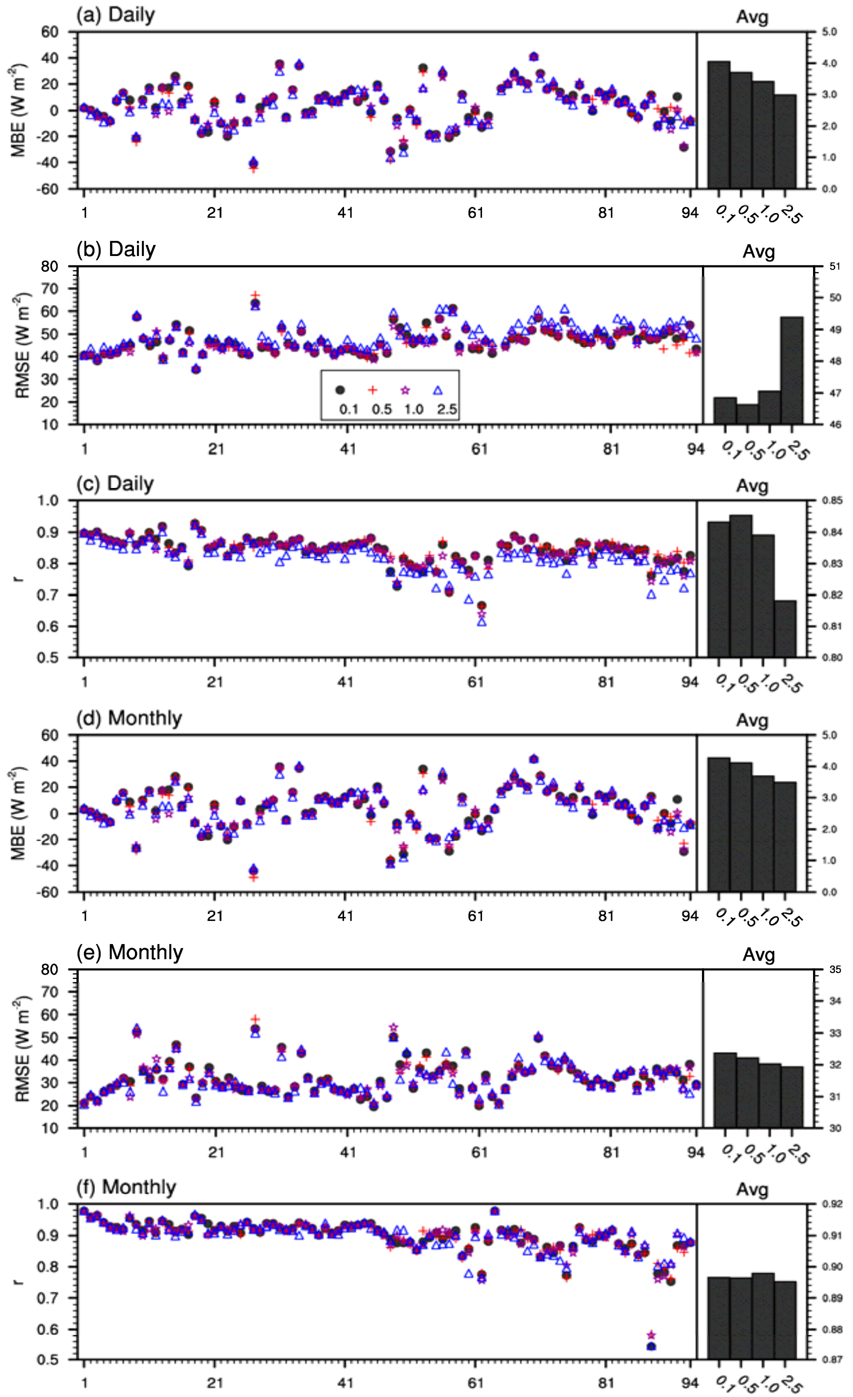
Products	Northeast	West	North	South
FY2C	4.7 (3%)	-0.1 (0.05%)	5.2 (3.1%)	6.0 (4%)
FLASHFlux	14.0 (9%)	14.2 (7.5%)	20.6 (12%)	24.7 (16.5%)
ERA-Interim	13.1 (8.4%)	25.9 (13.7%)	24.7 (14.4%)	30.2 (20.2%)
NCEP-DOE	41.2 (26.5%)	31.5 (16.7%)	55.2 (32.1%)	47.8 (31.9%)

(b) RMSE

Products	Northeast	West	North	South
FY2C	26.6 (17.1%)	31.8 (16.8%)	30.7 (17.9%)	33.4 (22.3%)
FLASHFlux	20.2 (13.0%)	29.6 (15.7%)	32.2 (18.7%)	32.5 (21.7%)
ERA-Interim	30.4 (19.6%)	37.5 (19.8%)	36.2 (21.1%)	41.5 (27.7%)
NCEP-DOE	50.2 (32.3%)	44.3 (23.4%)	64.6 (37.6%)	56.9 (37.9%)

Relatively weak correlation between the four DSSR products and OBS is seen over NC and SC: main reason is likely due to stronger seasonal variations in NEC (which increase the correlation with OBS) and larger effects of cloudiness, water vapor, and aerosols over NC and SC.

Effect of Spatial Resolution



the difference between the "point measurements" and the grid-box mean DSRR

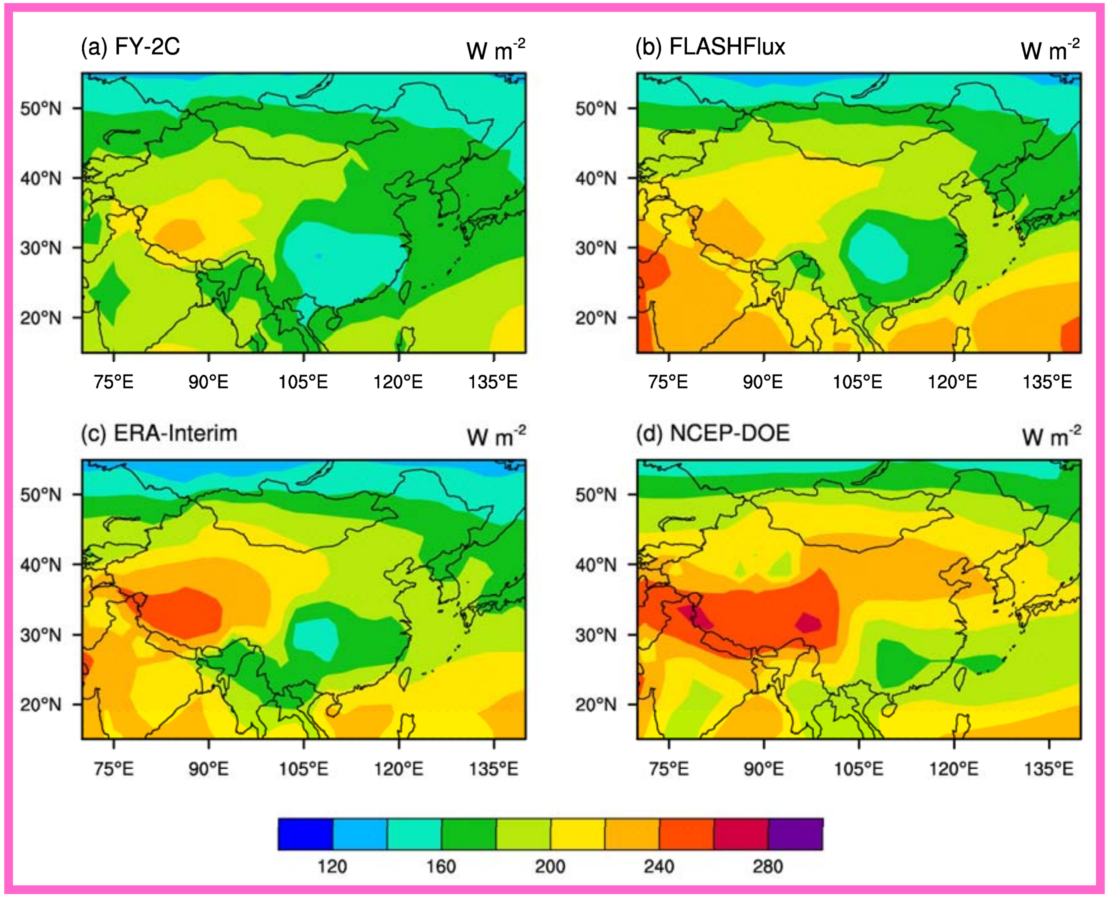
Spatial Res.	Daily RMSE	Daily *r*	Monthly RMSE	Monthly *r*
0.25°	4.89	0.9964	2.02	0.9992
0.5°	7.64	0.9917	2.99	0.9986
1.0°	9.71	0.9877	4.36	0.9976
2.5°	15.11	0.9691	6.39	0.9943

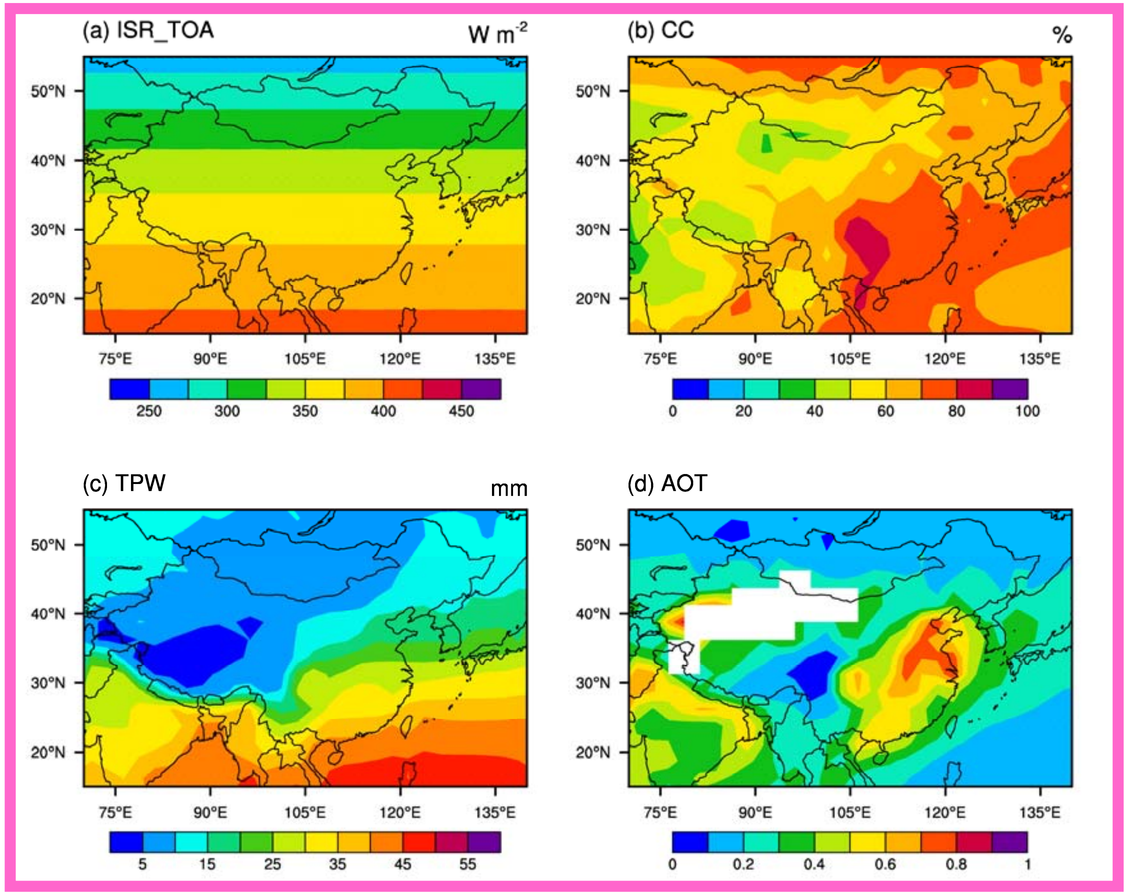
- As the grid size increases, the RMSE increases and the correlation coefficient decreases for daily data.
- RMSE for monthly-mean DSSR is substantially lower than that for daily DSSR and it remains very small (less than 7 Wm^{-2}) even as the scale difference increases.

Fig: The mismatch in DSSR data resolutions may contribute to daily DSSR, but not monthly.

4. Spatial and seasonal variations of DSSR

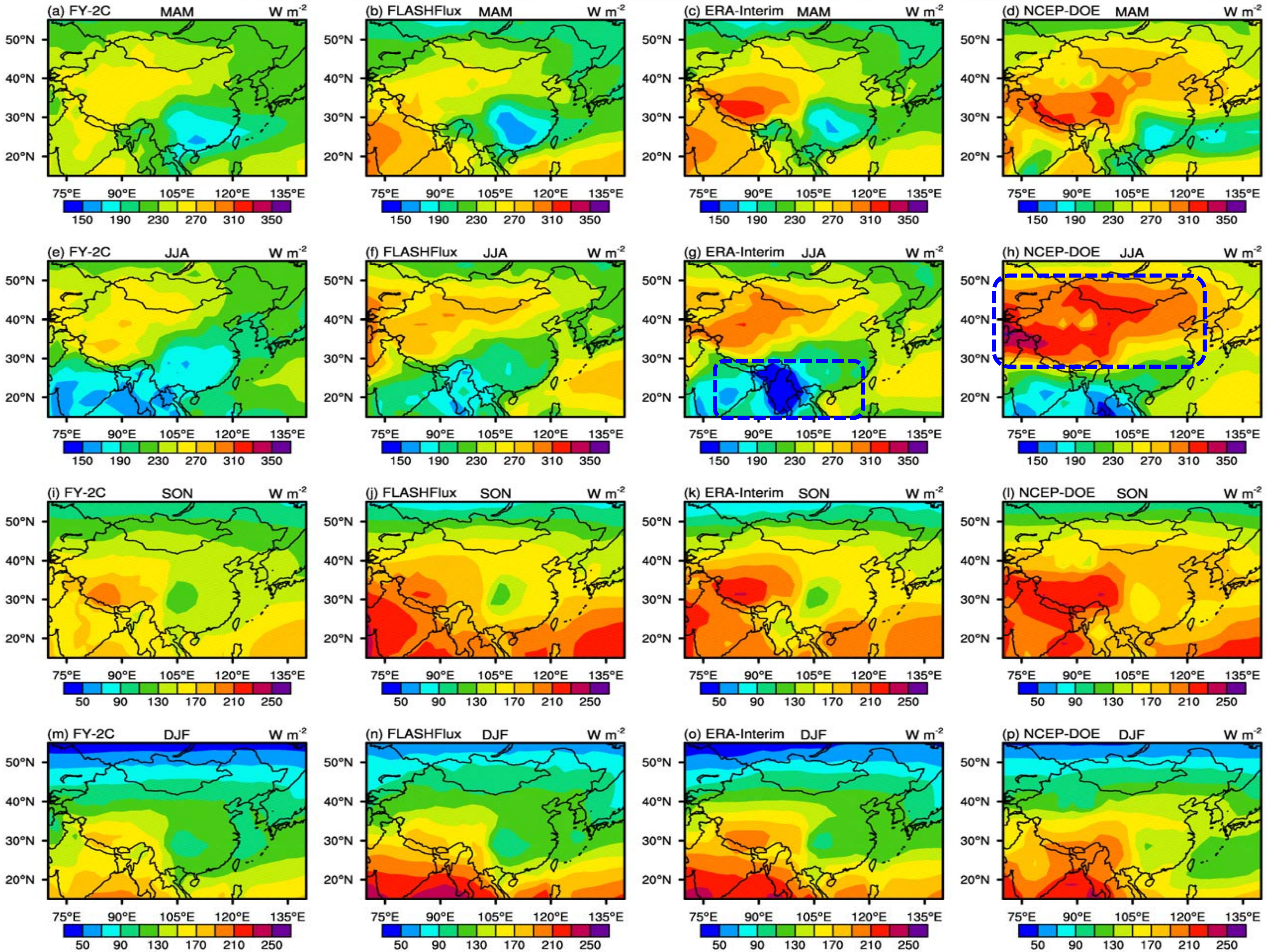
July 2006 to June 2009



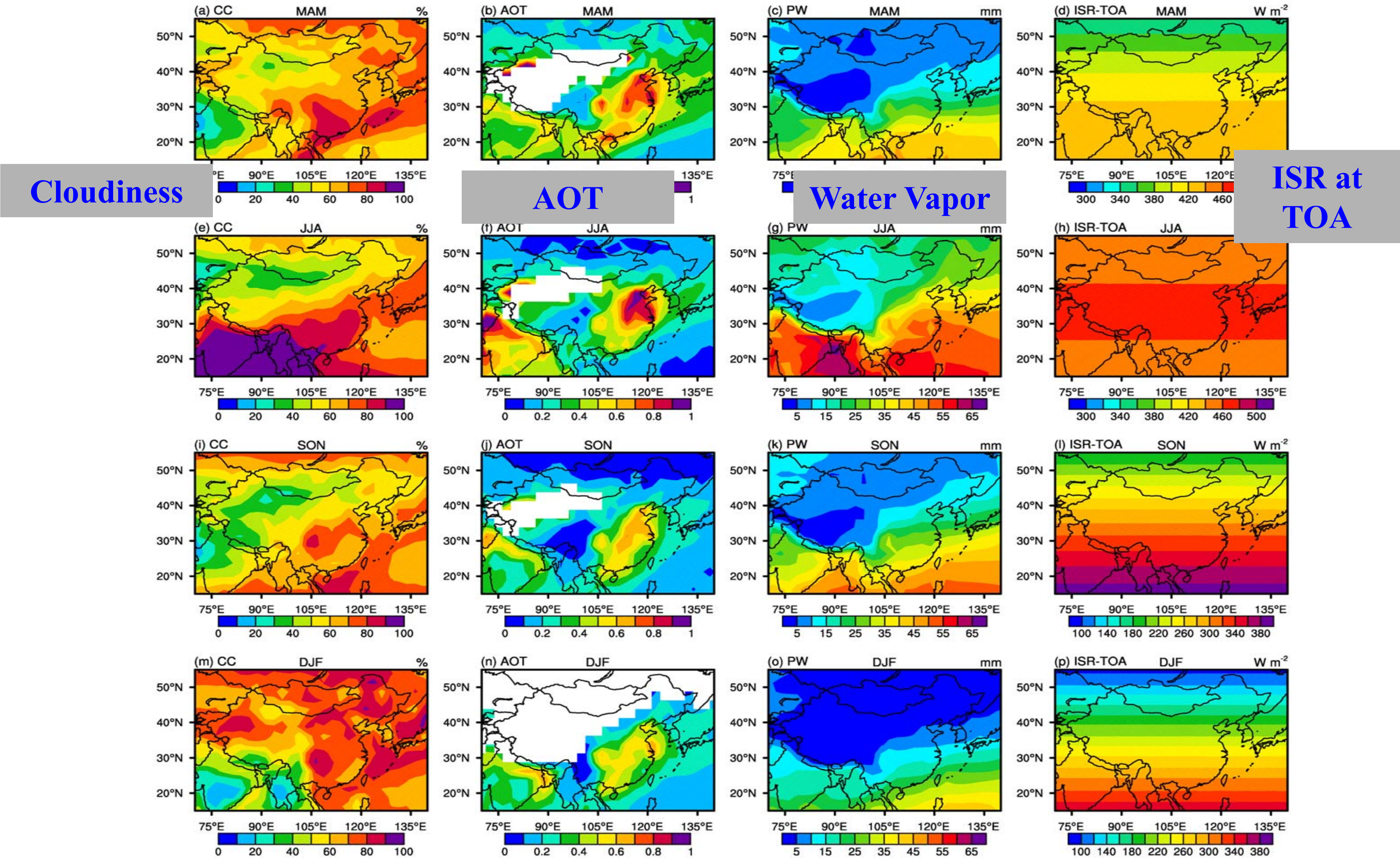


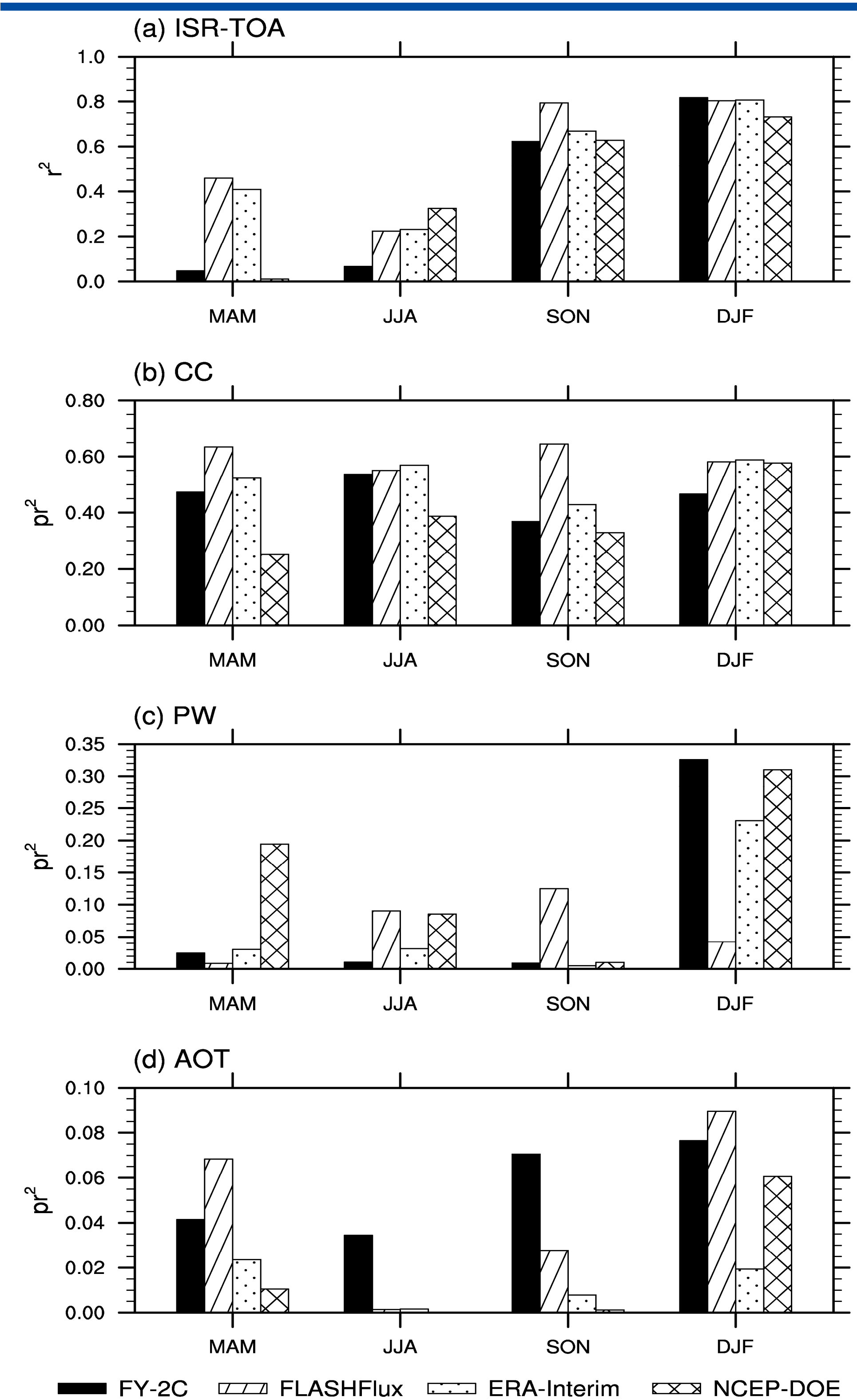
All four products show similar broad patterns, with high DSSR over western China, South Asia, and the North Pacific Ocean and low DSSR over southeastern and northeastern China.

Seasonal variations



Seasonal variations-impact factors





Spatial Partial Correlations

- **Cloud Cover: main factor in spring(MAM) and summer(JJA).**
- **ISR-TOA: r^2>0.62 in cold season.**
- **AOT and PW: smaller influences relatively.**

Parameterization scheme for satellite retrievals

Cloud optical thickness

- FY-2C: retrieved using the DISORT model, in which the atmospheric and surface parameters were taken from climatological monthly ISCCP C2 data averaged over 1983-1990. The unrealistic input data (instead of real-time states) could introduce errors in the temporal variations in the FY-2C data. These errors may contribute to the lower correlation.
- FLASHFlux: cloud information from MODIS observations, which may contribute to higher correlations with OBS.

Aerosol Optical Thickness

- FY-2C $$\alpha_{Aer} = 0.03 + 0.013\,\mathrm{PW}$$
- FLASHFlux $$\alpha_{Aer} = \tau_{Aer}(1-\omega_0) + \frac{1}{2}\tau_{Aer}\omega_0(1-g)$$

Parameterization scheme for satellite retrievals

Water Vapor

- **FY-2C: Lacis and Hansen [1974]**
- Li [1995] pointed out that Lacis and Hansen's parameterization caused significant errors in water vapor absorption, which may lead to large systematic biases (5-40 Wm^{-2}) for DSSR.
- the precipitable water data were from the climatological monthly ISCCP C2 dataset.

- **FLASHFlux: Gupta et al., [2001].**
- The comparisons between these two schemes by *Gupta et al*. [2001] suggested that there were large discrepancies in water vapor absorptivity for column-integrated precipitable water under 10 mm.
- FLASHFlux, on the other hand, used the data assimilation model products of the Goddard Earth Observing System, version-1 (GEOS-1).

5. Summary and Conclusions

- We have analyzed DSSR data from two satellite products (FY-2C and FLASHFlux) and two reanalyses (ERA-Interim and NCEP-DOE) over East Asia.
- The DSSR derived from the FY-2C satellite was analyzed for the first time in this study. Ground-based measurements from a BSRN site (Xianghe) and 94 stations from the CMA were used to evaluate the DSSR products.
- These DSSR products were then used to quantify the DSSR spatial and seasonal variations over East Asia during July 2006 – June 2009.

- DSSR data from FY-2C have much higher temporal and spatial resolution and show closer agreement with in situ OBS (lower bias).
- However, FY-2C shows a slightly lower correlation with OBS. This is likely due to deficiencies in the treatment of clouds, aerosols and water vapor, an unrealistic input data (of atmospheric and surface properties).

Thank You!

Comments and Suggestions to:

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