FY-2 On-orbit Operational Calibration Approach (CIBLE) and its Applications in FY-2D/E/F Satellites

Qiang Guo

National Satellite Meteorological Center, CMA

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NSMC

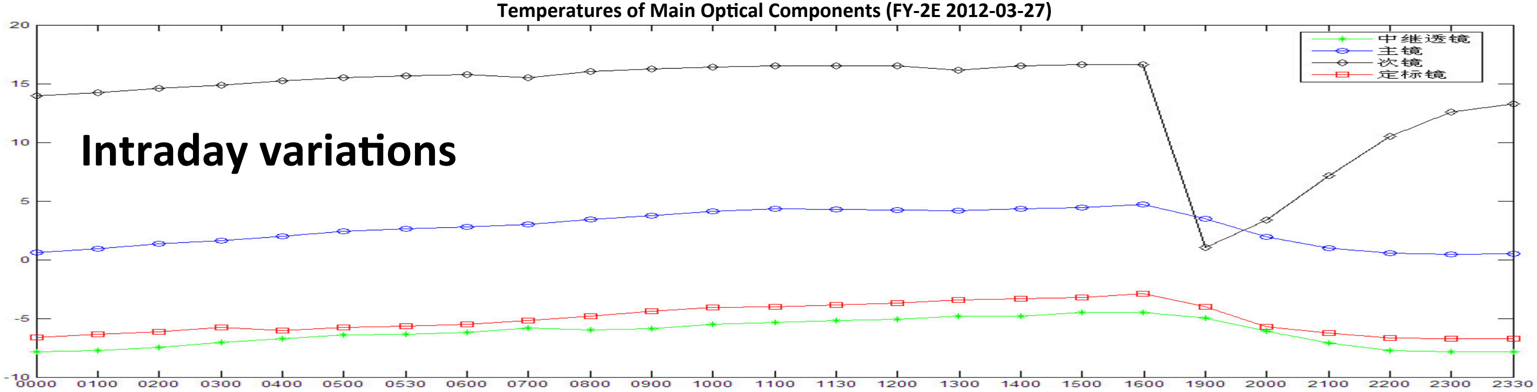
Outline

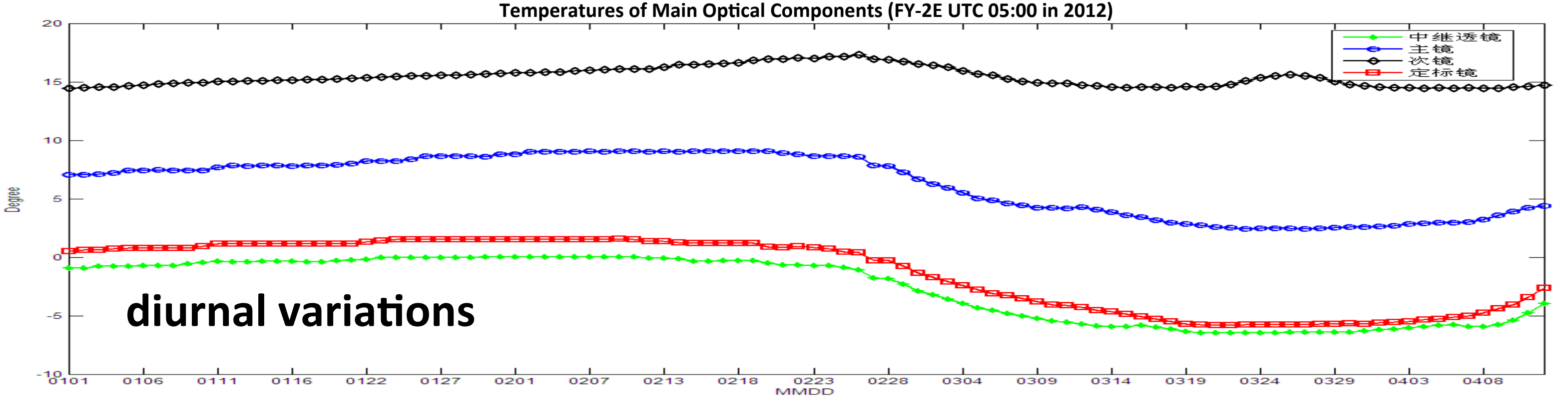
- **Brief Introduction of CIBLE for FY-2 Satellites**
  - *Basic Requirements for on-orbit calibration of FY-2*
  - *Primary Principles of CIBLE*
  - *Key Technologies of CIBLE*
- **Overview the Working Performance of CIBLE**
  - *Calibration Bias Evaluation*
  - *Quantitative Products & Applications*
- **Summary**

Main features of current calibration methods for FY-2 satellite

Types	Methods	Merit	Shortcoming
Before Launch	In-lab Cal.	High calibration accuracy, mainly used for sensitivity and amplification parameter determination	A few conditions cannot represent fully the on-orbit environment. Application for onboard payload is limited
After Launch	Inter-Calibration (AVHRR/HIRS)	Calibration performance of AVHRR is stable with long-term observation serials, and its spatial resolution is at the same order (Km) as FY-2 VISSR	Wide-band sensor, the performance of spectral response matching is limited and finally influence the calibration accuracy.
	Inter-Calibration (GSICS)	Calibration performance of IASI/AIRS is stable. Spectral response matching can be solved with these high spectral resolution sensors	Lower spatial resolution at 10^1 Km order (12/13.5), spatial matching depends on targets, especially for non-window band, e.g. water-vapor
	In situ Calibration	In situ target and atmospheric feature can be measured directly. Generally used for validation with high accuracy	Limited number of in situ targets with a relative narrower dynamic range for calibration
	Sea buoy Calibration	Calibration with uniform water body, whose radiometric feature is quite stable	Temperature measured by sea buoy differs from the surface one observed by onboard sensor. The range focus on high segment (>270K)

Main optical component temperature variation of FY-2E satellite

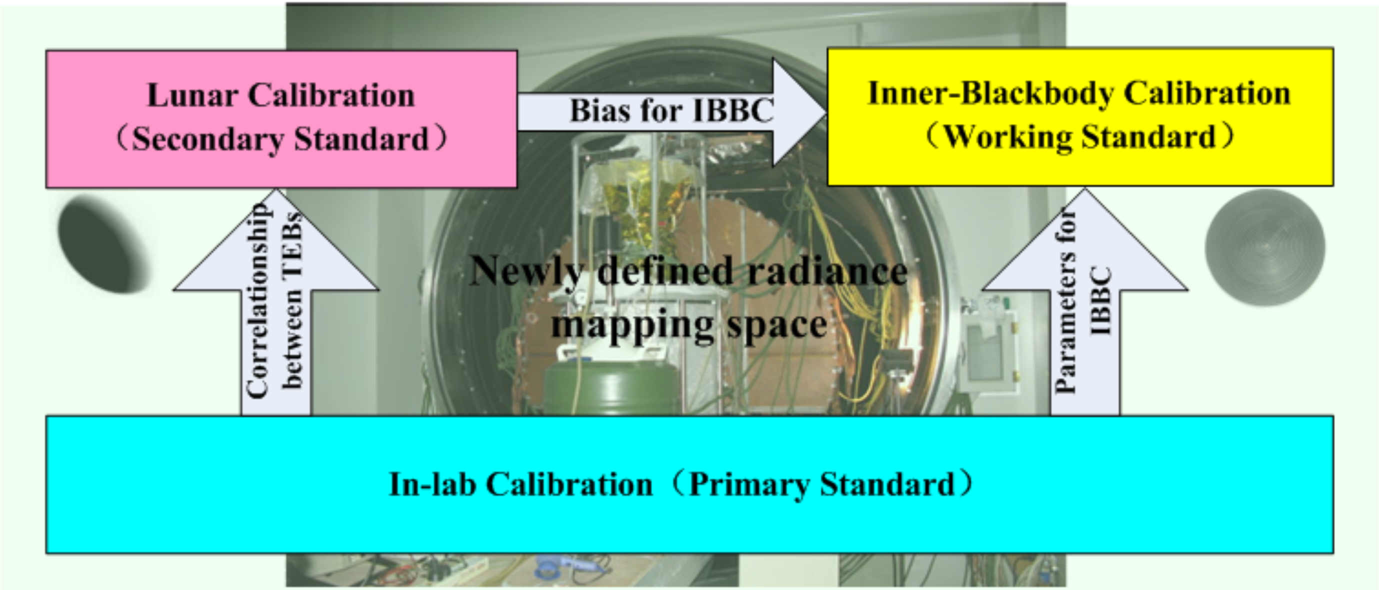




Thermal environment of FY-2 is continuously changing, which requires some new calibration source with high frequency and accuracy

Primary Principles of CIBLE

Calibration of Inner-Blackbody corrected by Lunar Emission (CIBLE)

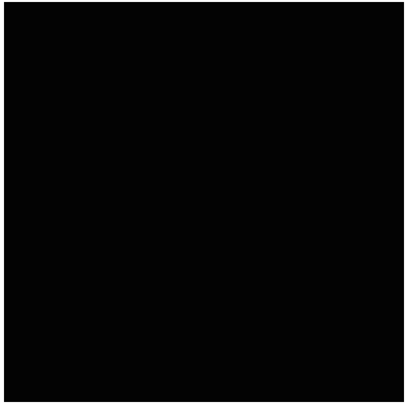


Based on the in-lab radiometric calibration with high accuracy, the on-orbit lunar calibration as well as the inner-blackbody one are proposed, and the CIBLE has been finally realized by radiation transformation between different reference standards.

Key Technique of CIBLE: Lunar Calibration (LC) in TEB

Feasibility of TEB Lunar Calibration:

The Moon's photometric stability is as perfect as 10^{-9} per year and it is surrounded by a black field in both reflective and emissive bands.
(*J. Atmos. Oceanic Technol.*, Vol.13, pp.360-374)



- **No significant emission or absorption feature;**
- **Surface temperature peak at infrared wavelength;**
- **Thermal emission spectra can be modeled as a function of illumination and viewing geometry.**

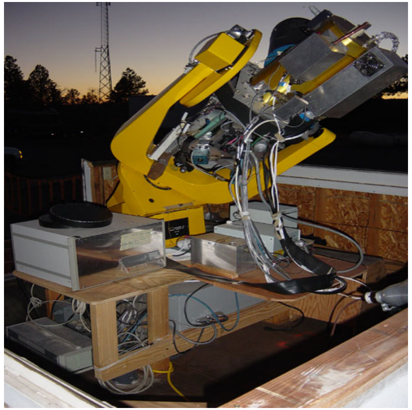
(*ICARUS*, Vol.92, pp.80-93)

For full moon with zero phase angle (*Opt. Eng., Vol.38, No.10, pp1763-1764*)

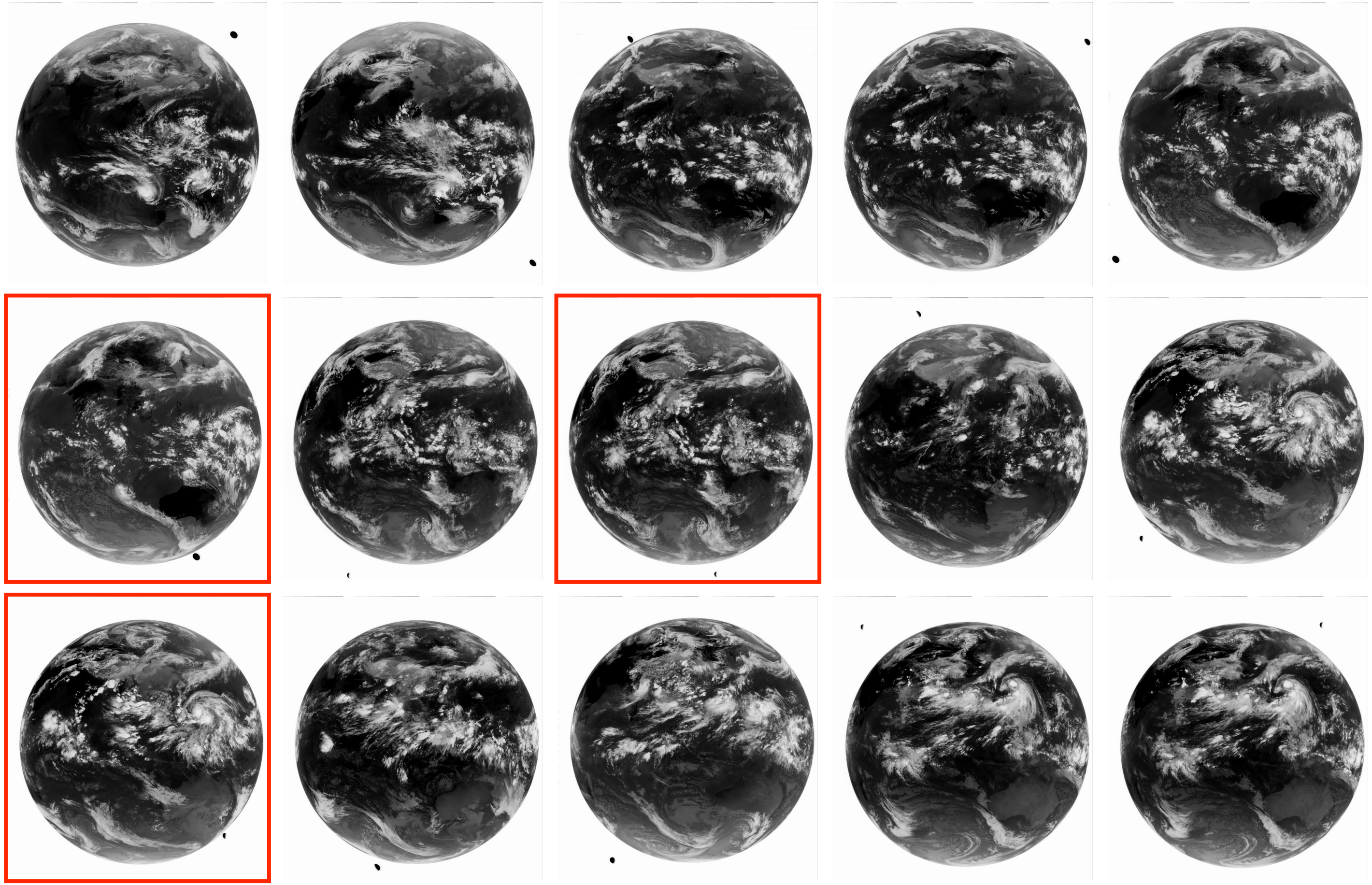
$$L_{\text{emitted}} = \varepsilon(\lambda) L^{bb}(\lambda, 390\ \text{K})$$

At present, lunar calibration is mainly applied in RSBs, for example MODIS, SeaWiFs and GOES imager. In 2010, Xiong *et al.* used on-orbit lunar observations to evaluate the calibration performance of MODIS's MIR band.

Lunar Obs. on ground: RObotic Lunar Observatory (ROLO) Project

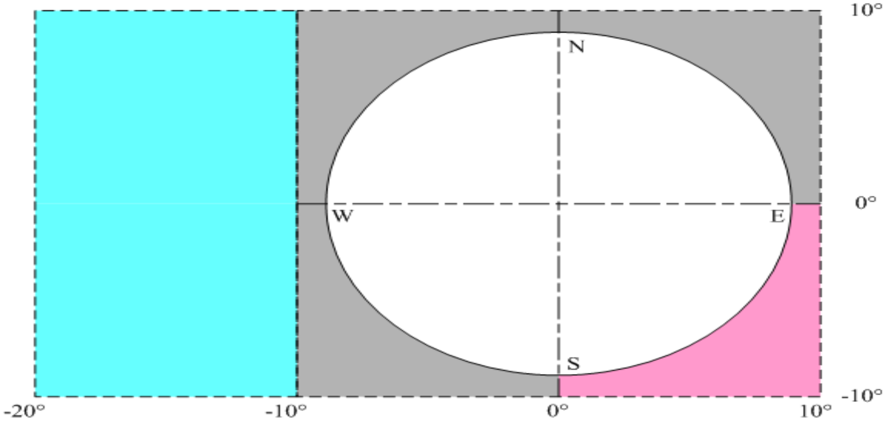


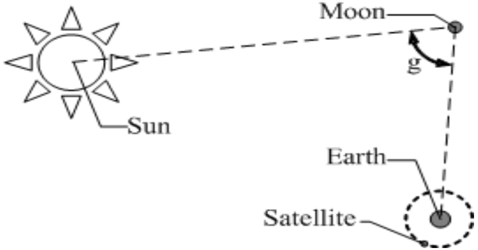
Moon's position distribution for LC in TEBs (Examples as for FY-2E)



- The Moon could appear in anywhere of the cold space outside of the full Earth disc;
- To decrease the influence of stray light on the LC results, it is recommended that the South-East corner of the cold space where the Moon appears is suitable for LC

Continuous Moon Observations with regional-rapid-scan mode of FY-2F in Apr. 16, 2012





g is Moon's phase and satisfied with:

$$P = \frac{1+\cos(g)}{2}$$

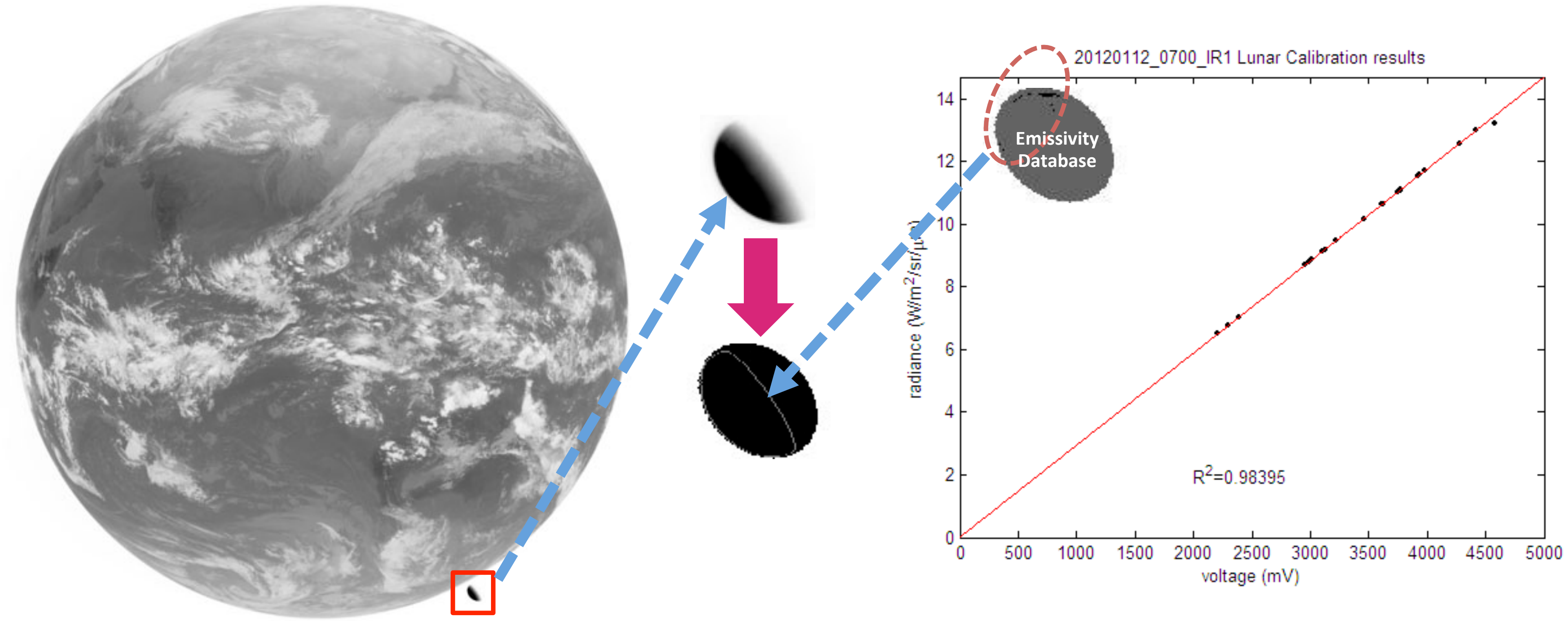
Aft. Cps. 5:1, VIS

Aft. Cps.1:1

Aft. Cps. 5:1, IR1

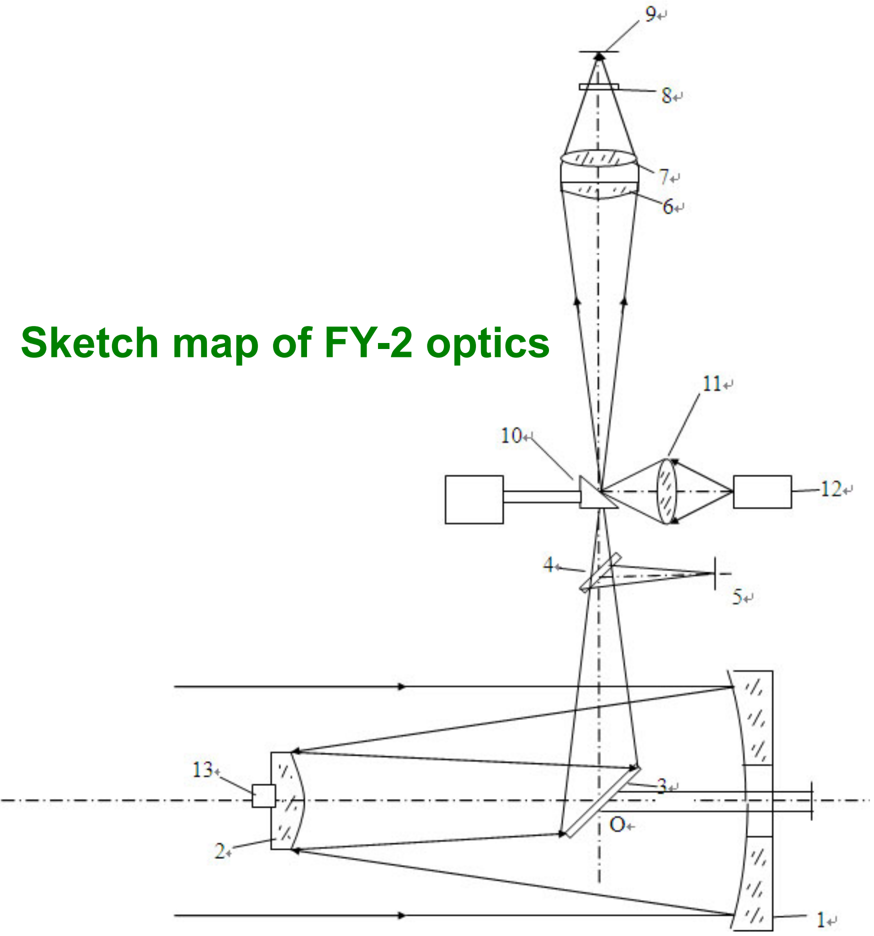
Aft. Cps.1:1

Typical example of LC for FY-2E at UTC07:00, Jan.12, 2012



Inner-Blackbody Calibration (IBBC) for FY-2 Satellite TEBs

Sketch map of FY-2 optics

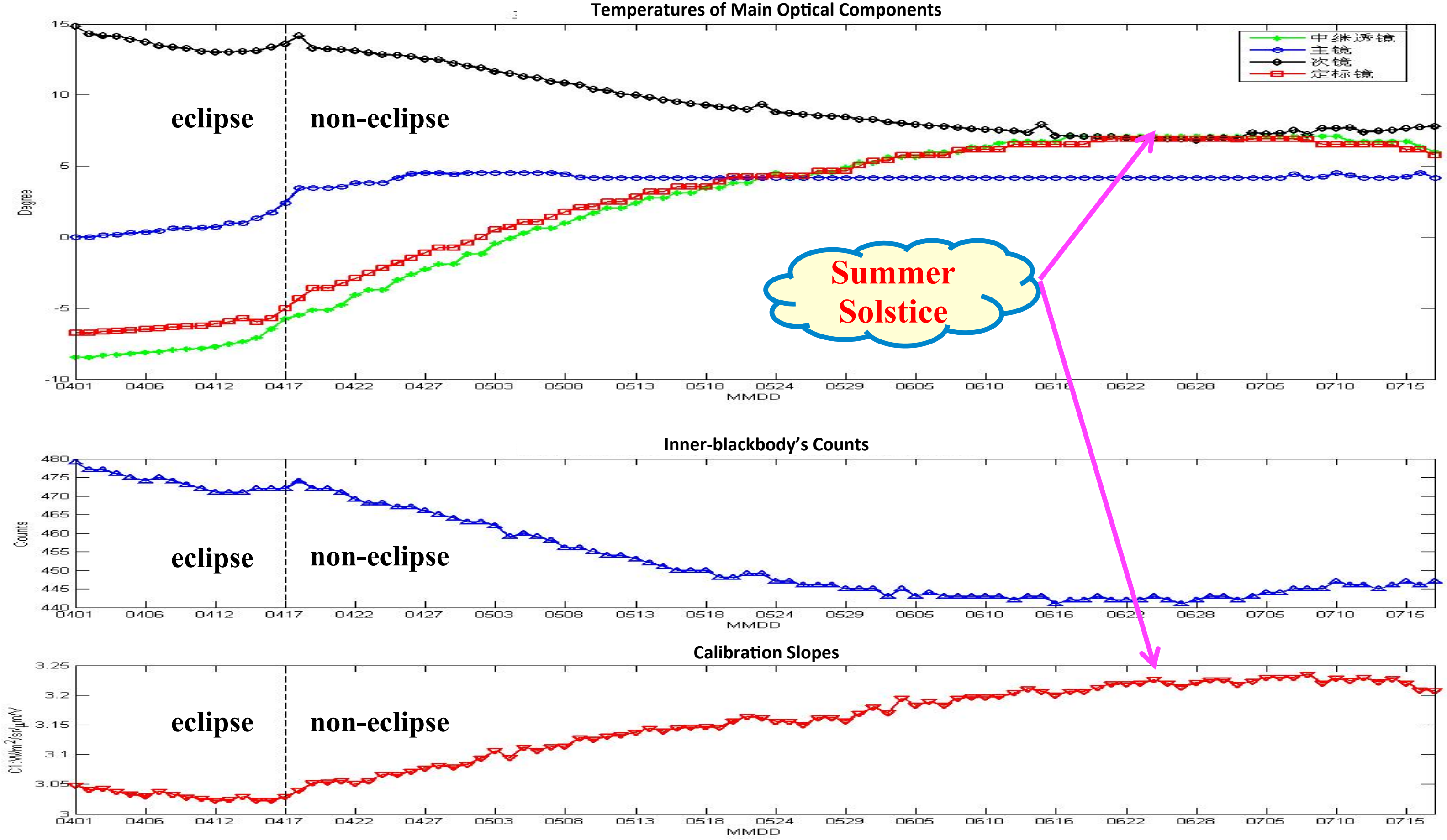


Main Optical Components
1: Primary Mirror
2: Secondary Mirror
6/7: Relay lens
10: Mirror for Cal.
12: Inner-Blackbody

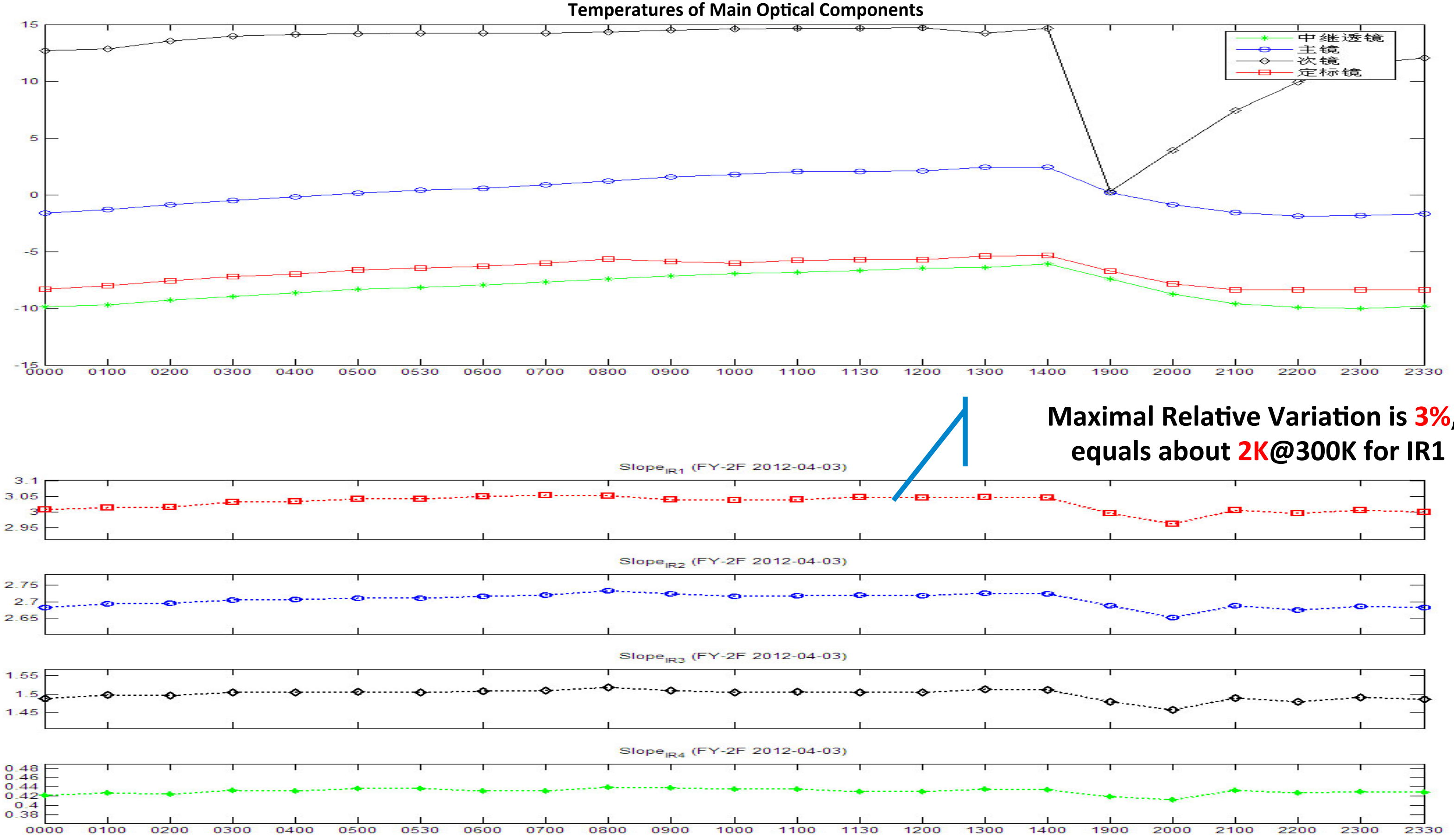
Main Challengers for IBBC of FY-2 satellite

- The radiometric contribution of front-optics, including primary and secondary mirrors, has different effects on IBBC as well as space-view.
- The thermal environment of aft-optics for FY-2 *cannot* be controlled perfectly.

Calibration slope's diurnal variation for FY-2F at UTC 0500 between Apr. 1 and Jul. 20, 2012

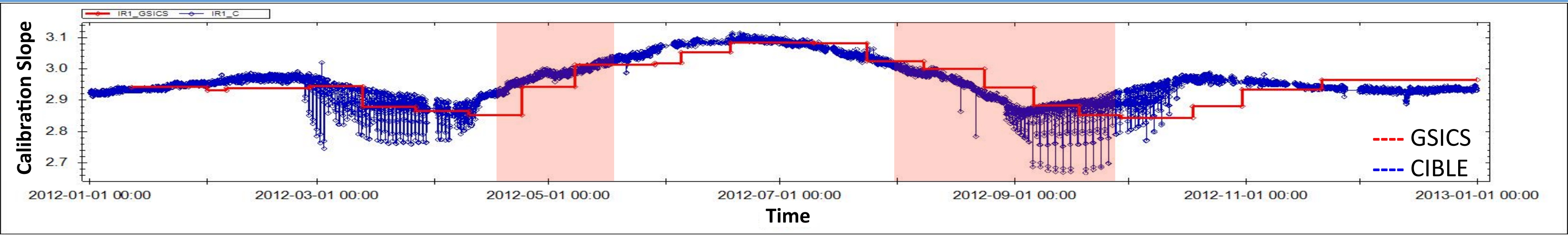


Calibration slope's intraday variation for FY-2F during satellite eclipse period

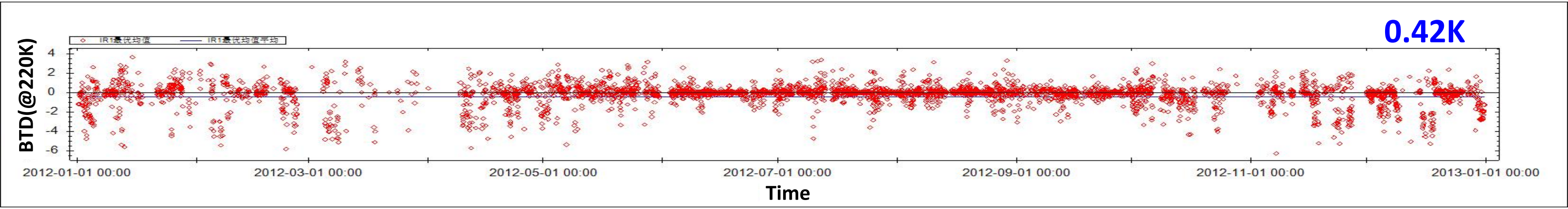


Maximal Relative Variation is 3%, which equals about 2K@300K for IR1 band

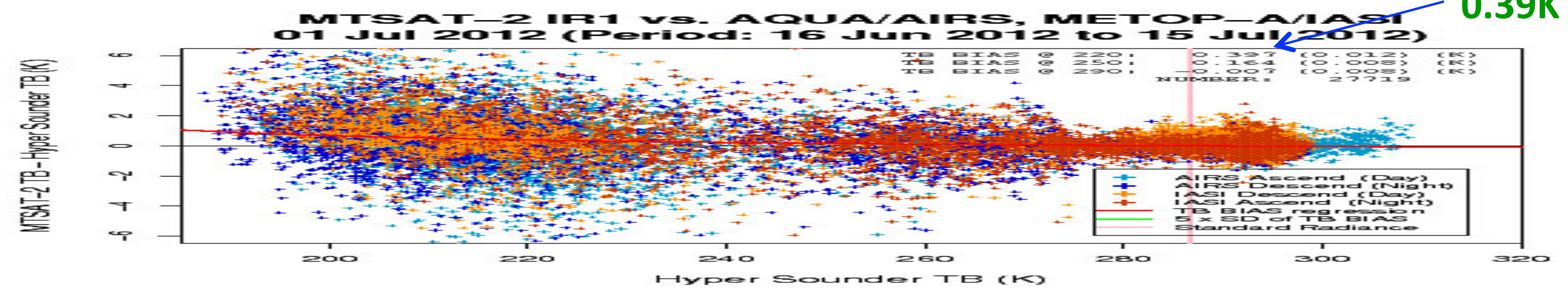
Overview the Working Performance of CIBLE

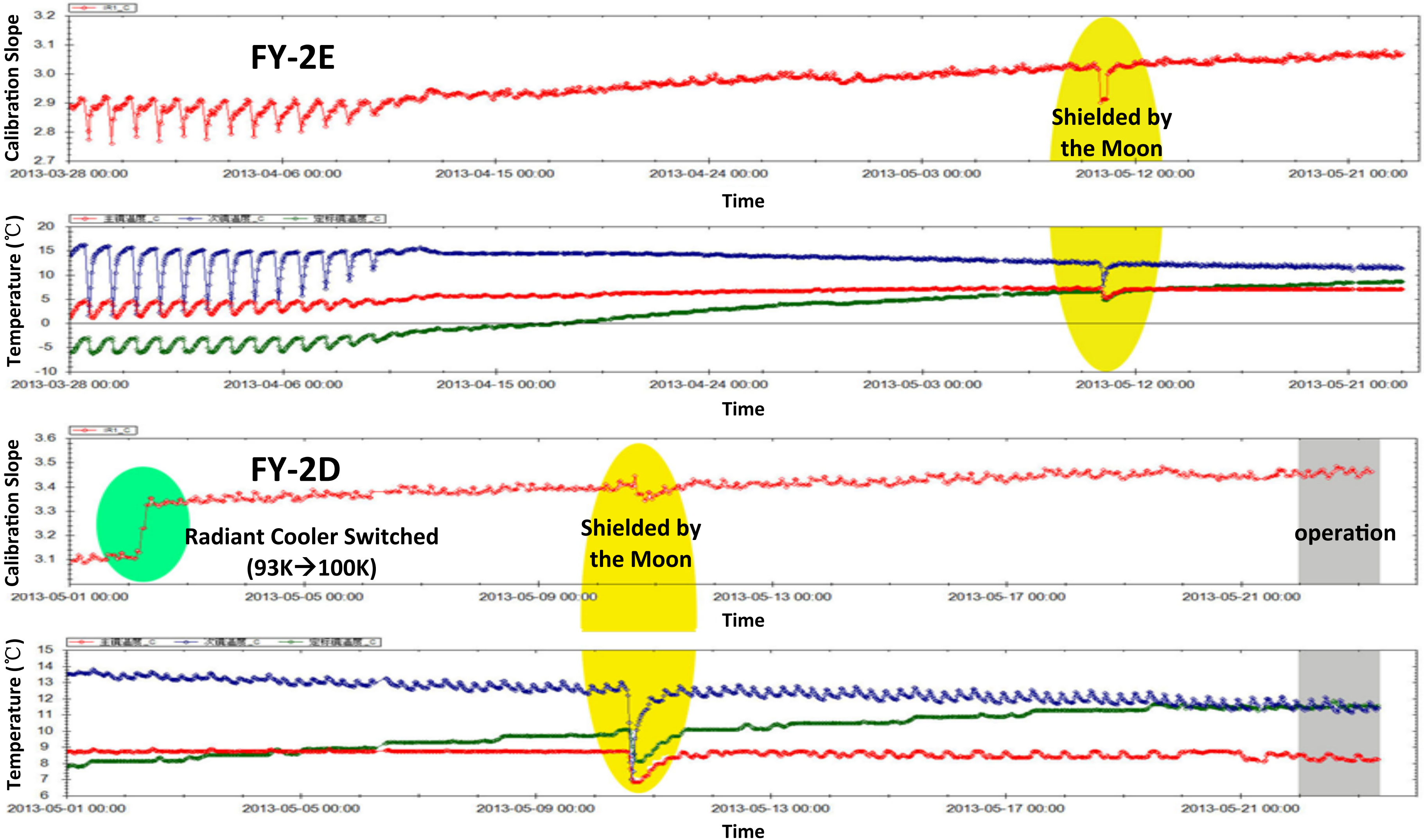


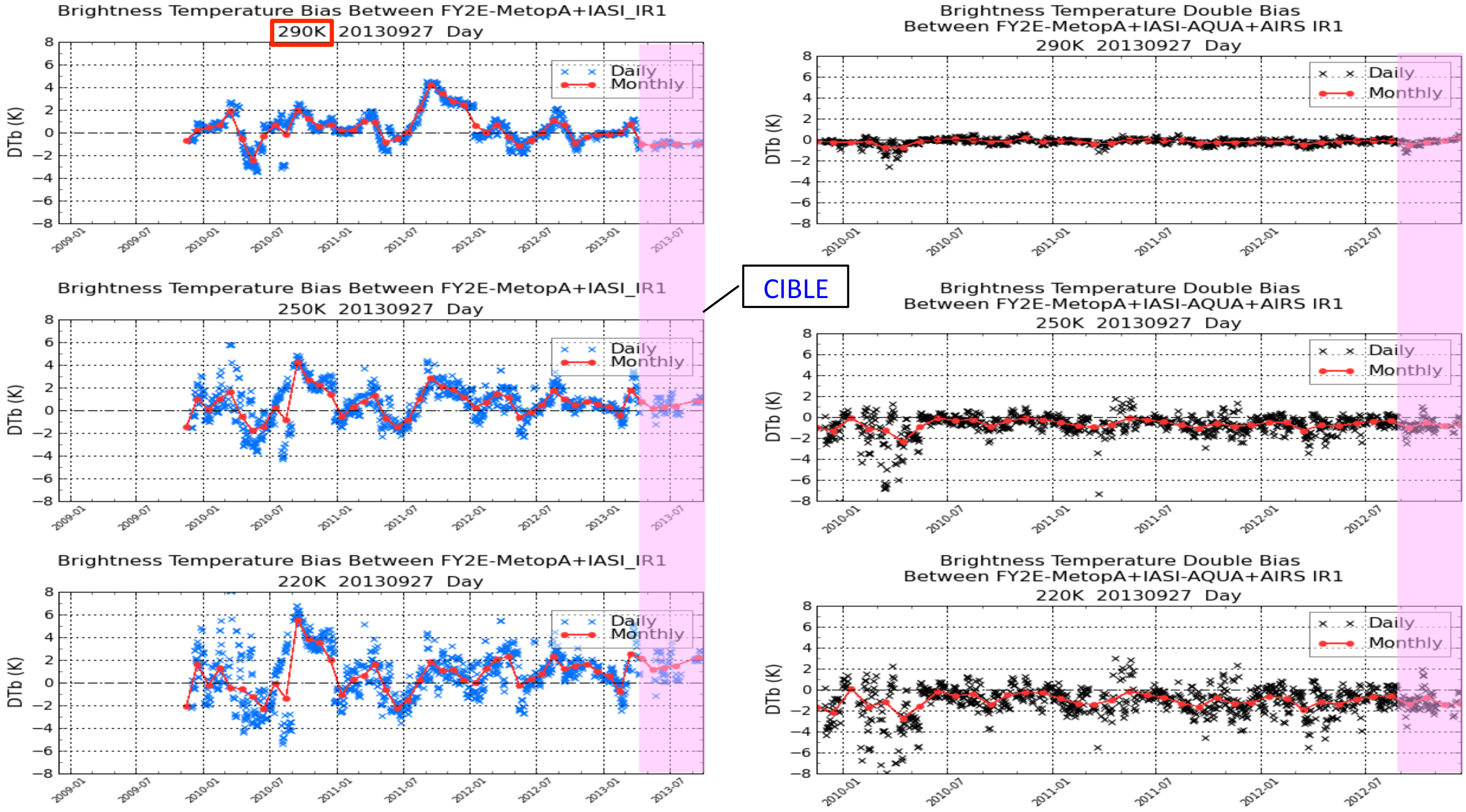
Calibration slope comparison between CIBLE and O.C. in IR1 band during 2012



Analysis of CIBLE's accuracy in IR1 band during 2012 for FY-2E



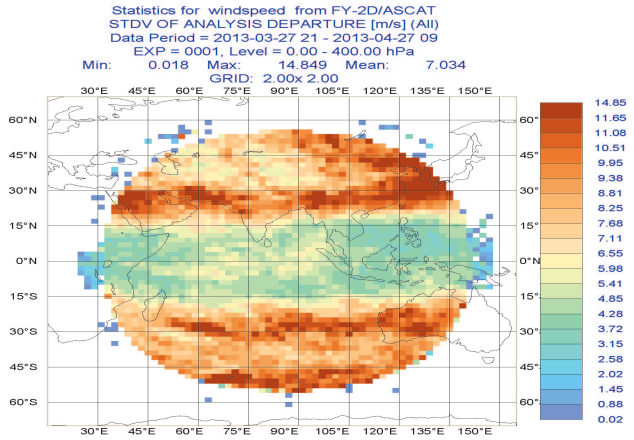

FY-2E
Calibration Slope
Shielded by the Moon
Time
Temperature (℃)
FY-2D
Radiant Cooler Switched (93K→100K)
Shielded by the Moon
operation
2013-03-28 00:00
2013-04-06 00:00
2013-04-15 00:00
2013-04-24 00:00
2013-05-03 00:00
2013-05-12 00:00
2013-05-21 00:00
2013-05-01 00:00
2013-05-05 00:00
2013-05-09 00:00
2013-05-13 00:00
2013-05-17 00:00



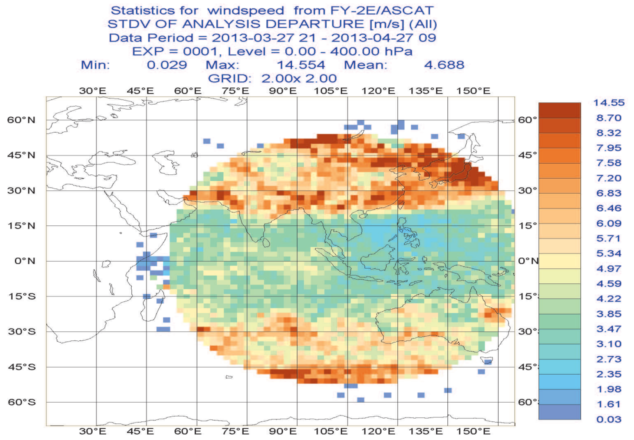
http://gsics.nsmc.cma.gov.cn/queryIndexPage.action

AMV analysis for Water-Vapor band between Mar. 27 and Apr. 27 in 2013 for FY-2E

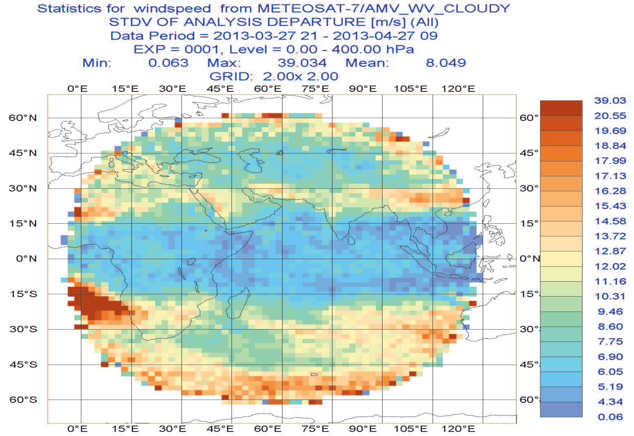
FY-2D
7.034m/s
(GSICS)



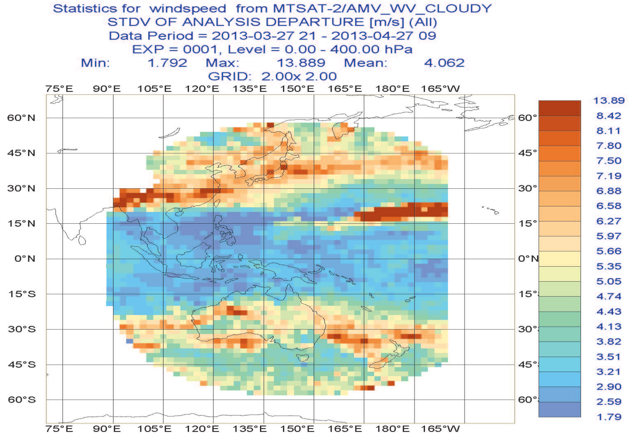
FY-2E
4.688m/s
(CIBLE)



MET7
8.049m/s

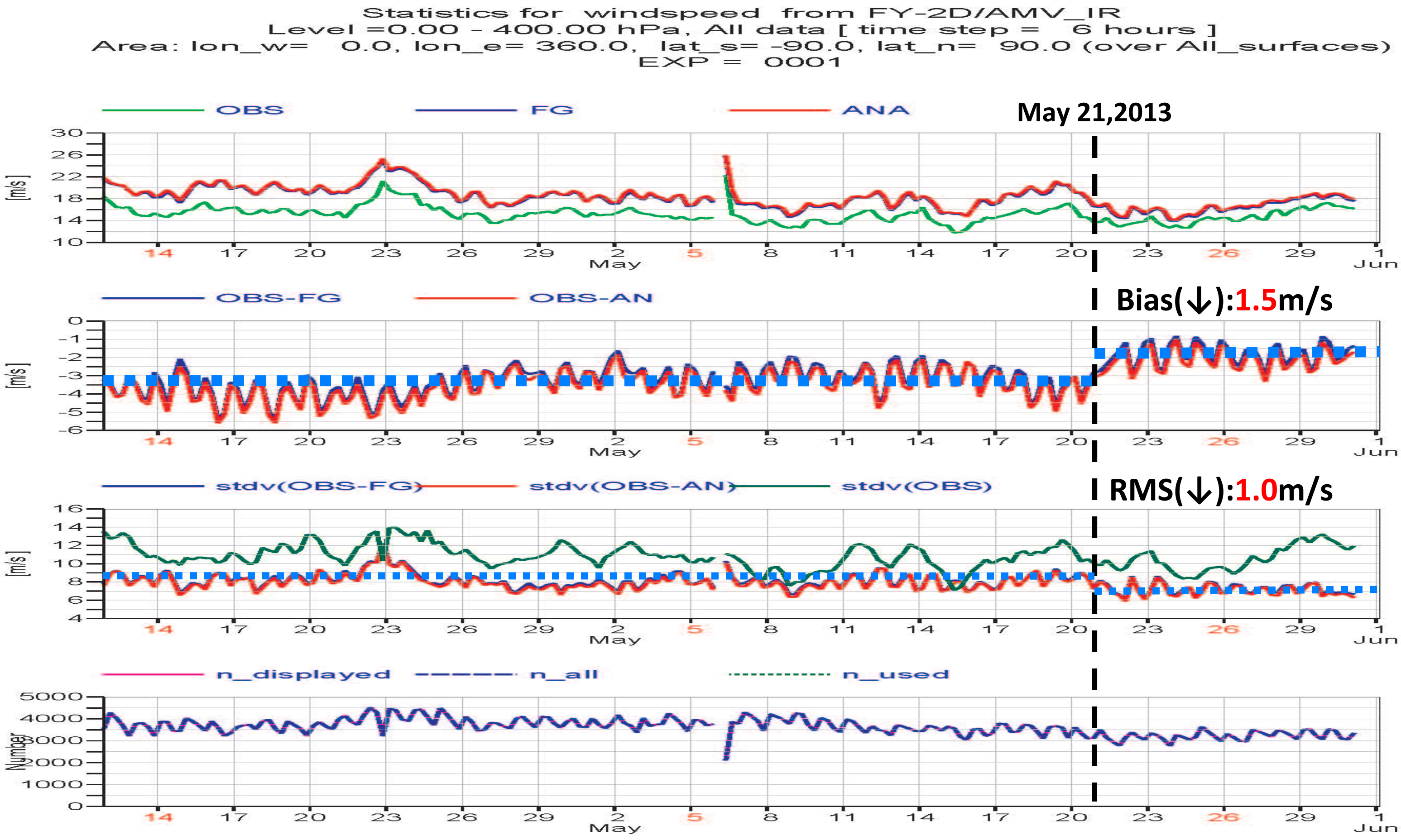


MTS2
4.062m/s



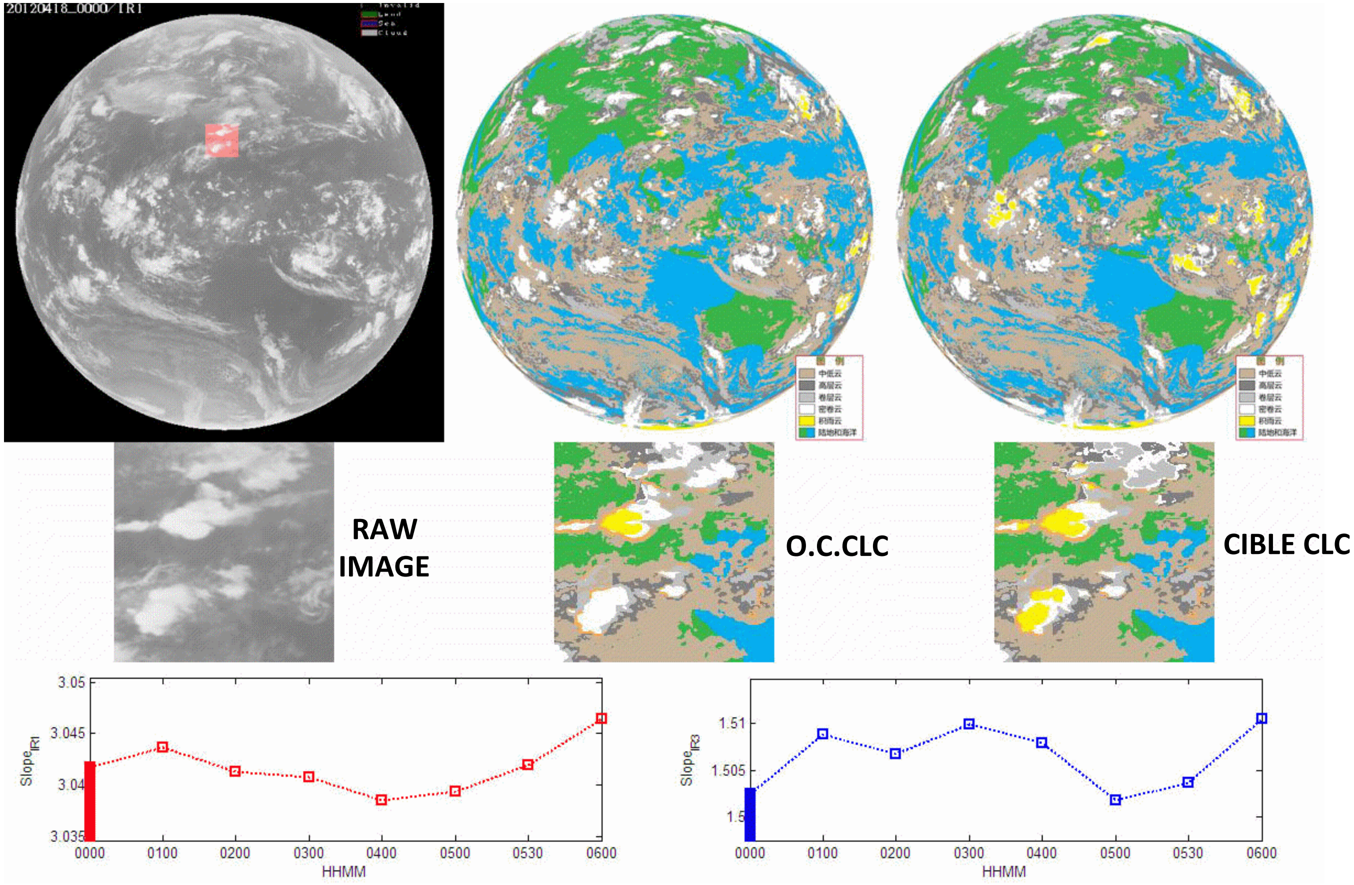
http://www.ecmwf.int/products/forecasts/d/charts/monitoring/satellite/amv/windspeed/

AMV analysis for Infrared band between before vs. after CIBLE switch of FY-2D



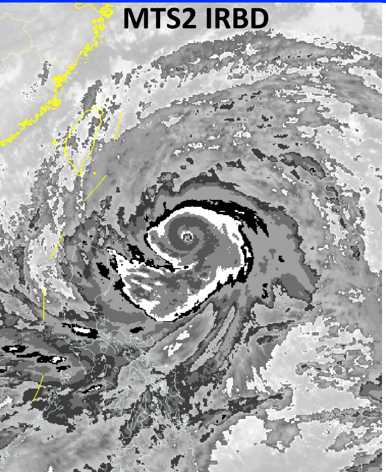
http://www.ecmwf.int/products/forecasts/d/charts/monitoring/satellite/amv/windspeed/

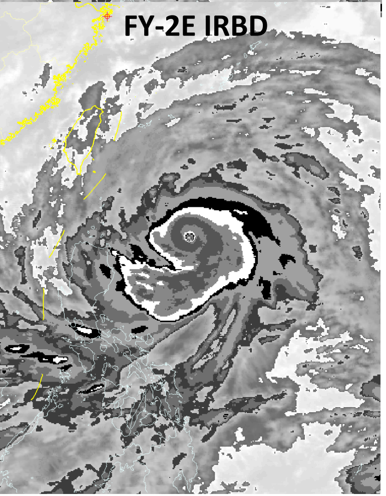
Cloud Classification (CLC) sample in April 18, 2012 for FY-2F



- The left animation demonstrates a typical convection procedure captured by FY-2F in 2012;
- With the O.C. results provided by GSICS method, the CLC for the high cloud illustrating the heavy convection is discontinuous within a six-hour period;
- If we use the CIBLE one, however, with the same algorithm, the performance of CLC has been improved significantly with a smooth outcome of CLC for high cloud.

No.19 Super Typhoon "USAGI" Monitoring Application with FY-2E in 2013（DVORAK）

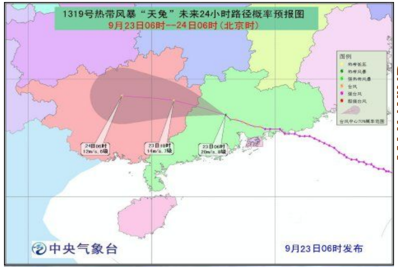




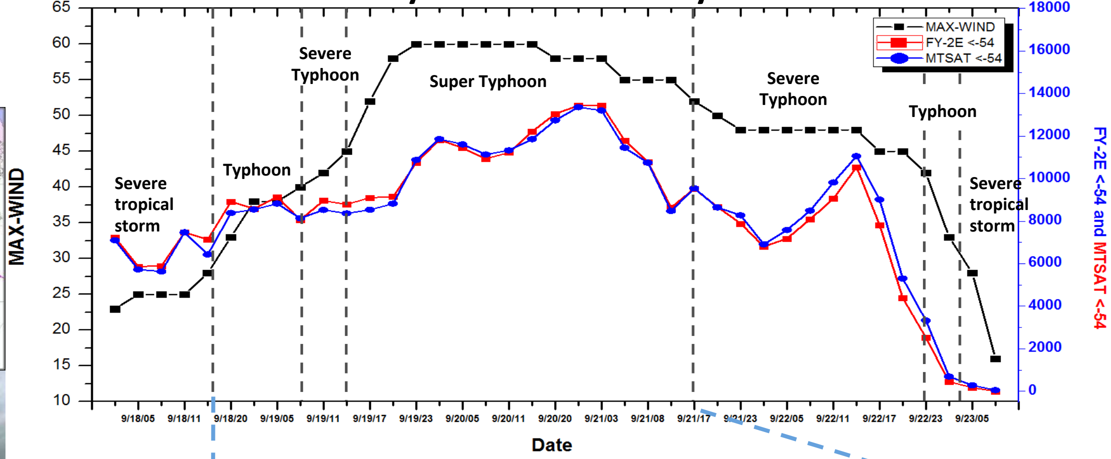
BJT03:00 Sep.20, 2013

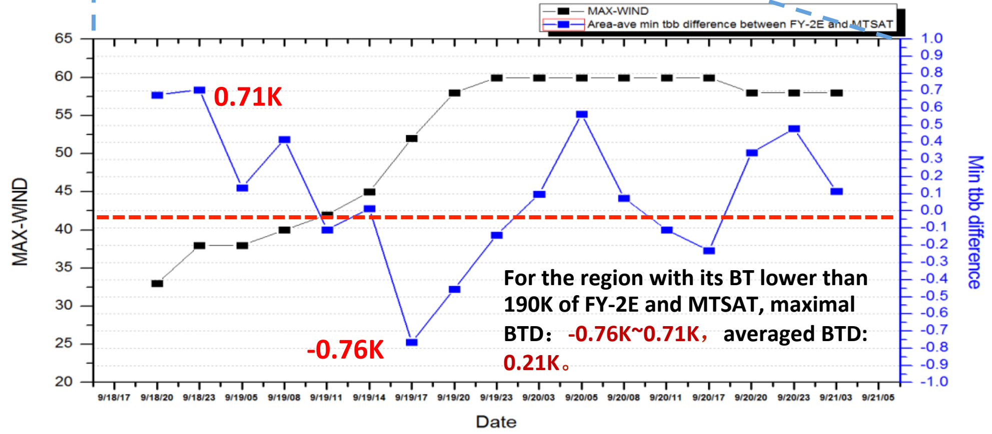
BT_{min_FY2E} =187.43K

BT_{min_MTS2}=186.97K

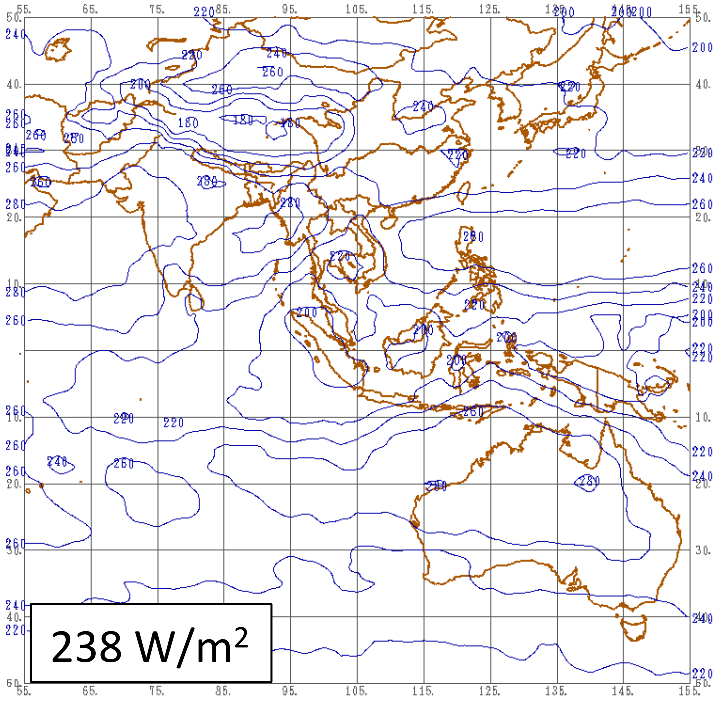


Area of main-body cloud vs. intensity variation



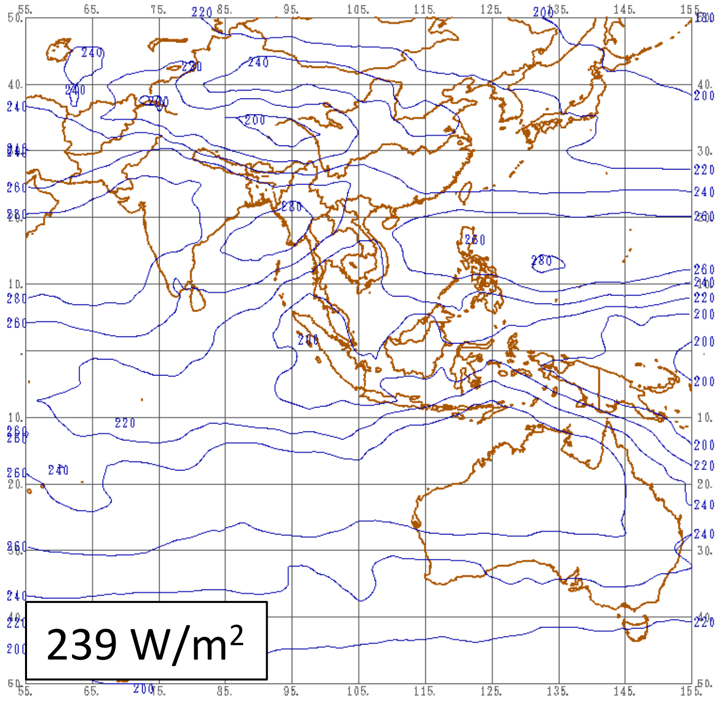


For the region with its BT lower than 190K of FY-2E and MTSAT, maximal BTD：-0.76K~0.71K， averaged BTD: 0.21K。



NCEP NOAA-18月平均OLR（2013年4月，局部，单位：瓦/米**2）

NOAA-18 Averaged OLR in April,2013

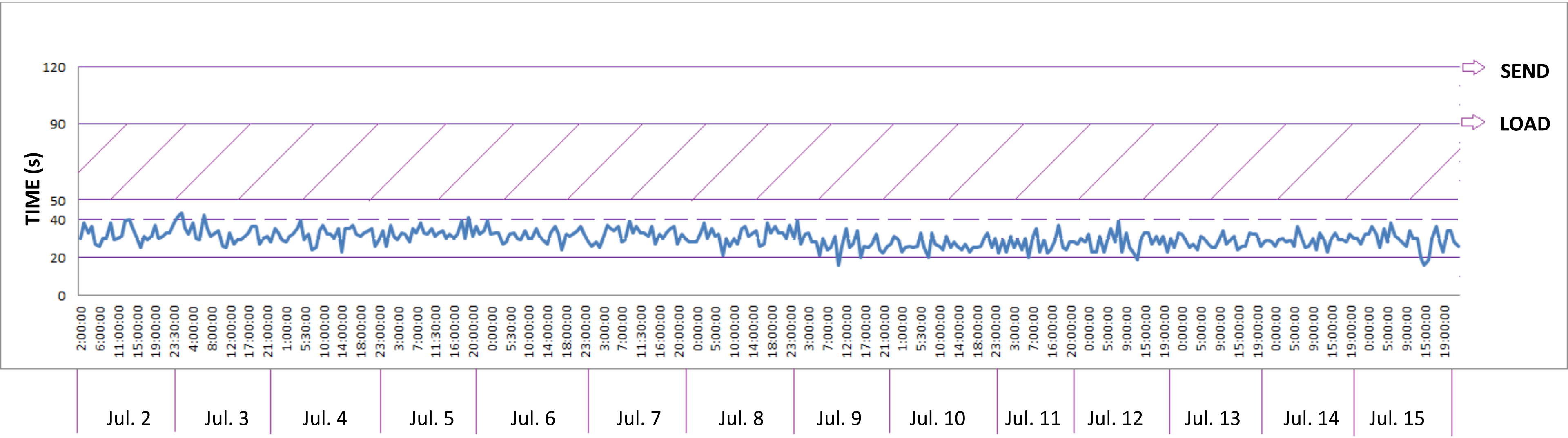


业务系统FY-2E月平均OLR（2013年4月，单位：瓦/米**2）

FY-2E Averaged OLR in April,2013

Notes: **OLR** references to **O**utgoing **L**ong-wave **R**adiation

Timeliness analysis for CIBLE in FY-2 satellites



ΔT(Processing time for CIBLE): Min=16s, Max=43s

The latest calibration results of CIBLE will be added in S-VISSR stream at the beginning of No.201 scanning line. (about 2 minutes delay)

Summary

• The CIBLE method has been independently developed in China by using both lunar calibration (LC) and inner-blackbody calibration (IBBC) for TEBs, which is widely considered to be a prominent progress in terms of operational calibration for FY-2 serial satellites .

• The CIBLE software has been operational working in ground segments of FY-2F, FY-2E and FY-2D satellites since July 21, 2012, March 27 and May 21, 2013 respectively, whose calibration accuracies are evaluated to be superior to 1K@300K. At the same time, the difficulty of calibration with high accuracy for the radiometric response, which varies rapidly with VISSR's thermal environment, has been conquered successfully.

• A new on-orbit radiometric reference for TEB calibration has been primarily setup in China, which is supposed to be benefit to other payloads' calibration in similar bands.

Thanks for your attention!