12th International Winds Workshop (IWW12)

Calibration of Inner Blackbody corrected by Lunar Emission (CIBLE)

FY-2 On-orbit Operational Calibration Approach (CIBLE) and its Benefit to FY-2D/E AMV Products

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- Brief Introduction to CIBLE
  - Basic Principles & Key Technologies
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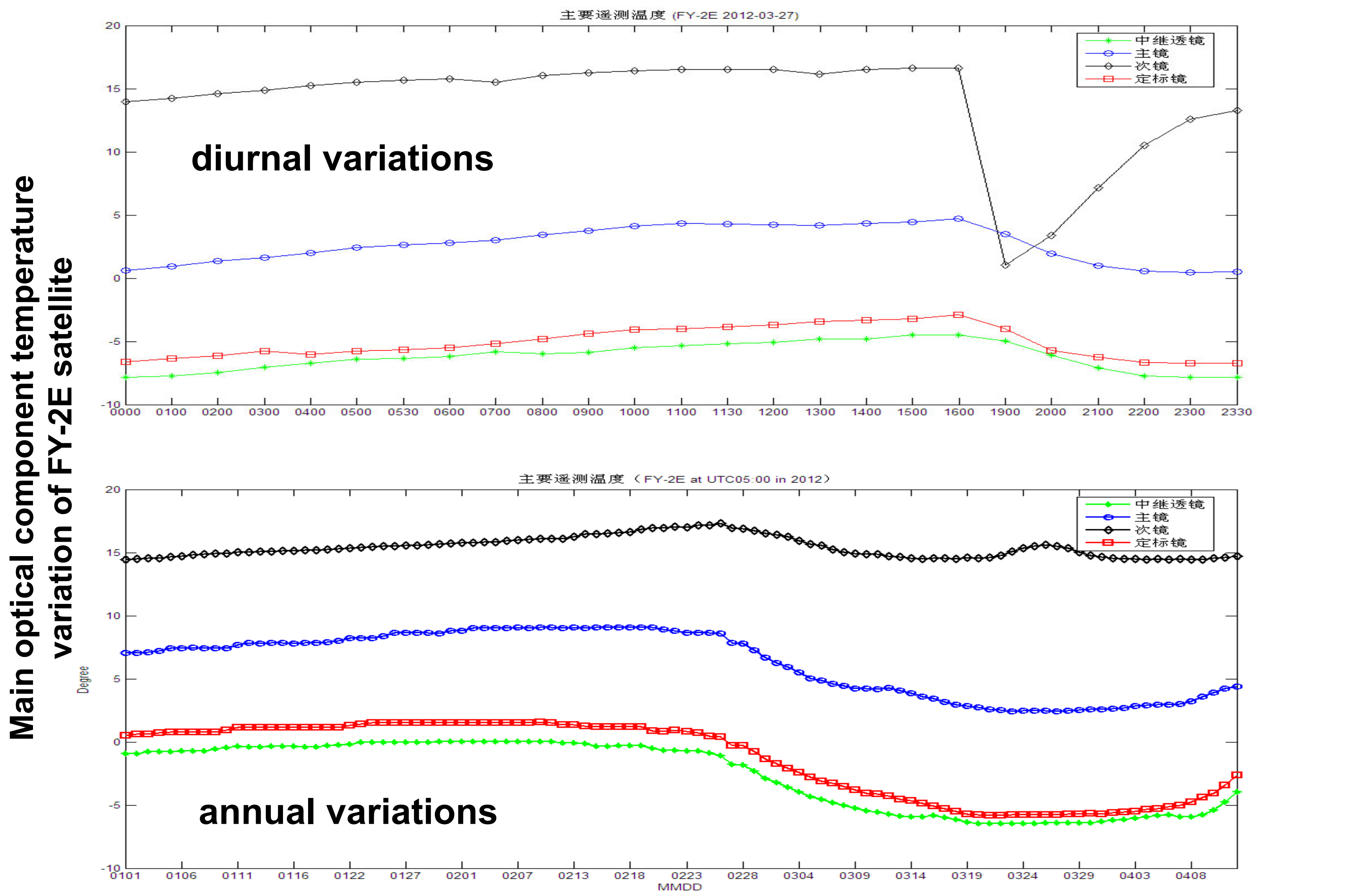
Current Status & Challenge for FY-2 Calibration

Satellite	Launch Time	Application and Main Merits
FY-2A	1997.06.10	Subseries 1st , Experimental Satellite: Validation of main detecting functions and some key technologies of the whole system are completed.
FY-2B	2000.06.25	
FY-2C	2004.10.19	Subseries 2nd , Operational Satellite: ▪ Operational Stabilized Systems for both space and ground segments ▪ INR technique has been conquered ▪ Inter-calibration and main products have been in operation
FY-2D	2006.12.08	
FY-2E	2008.12.23	
FY-2F	2012.01.13	Subseries 3rd , Operational Satellite: Quantitative applications are willing to be improved in an overall scale, where **the increase of calibration accuracy is one of the most important factors**!

Main features of current calibration methods for FY-2 satellite

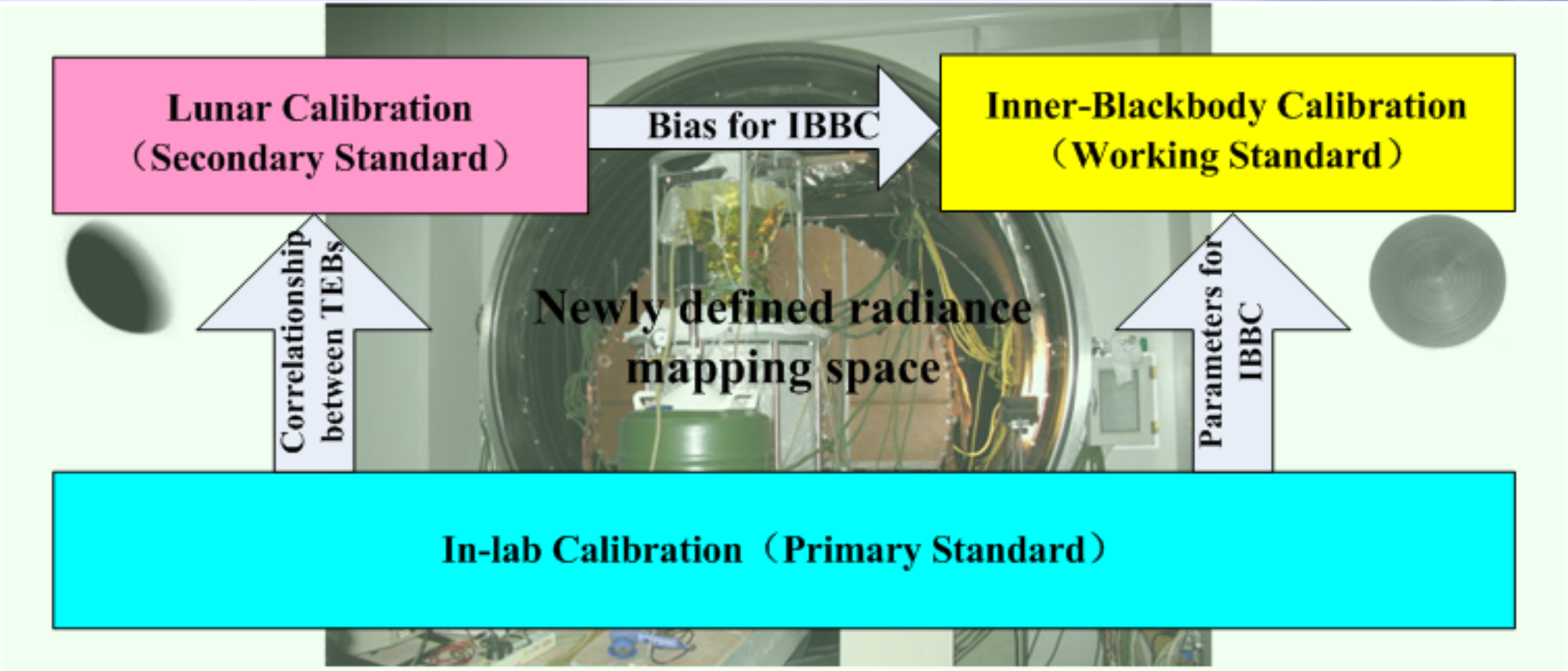
Types	Methods	Merit	Shortcoming
Before Launch	In-lab Cal.	High calibration accuracy, mainly used for sensitivity and amplification parameter determination	A few conditions cannot represent fully the on-orbit environment. Application for onboard payload is limited
After Launch	Inter-Calibration (AVHRR/HIRS)	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)



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

Brief Introduction to CIBLE

Basic Principles of 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.

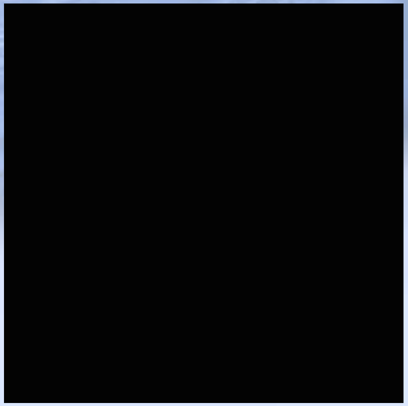
Key Technique of CIBLE: Lunar Calibration (LC) in TEB

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)

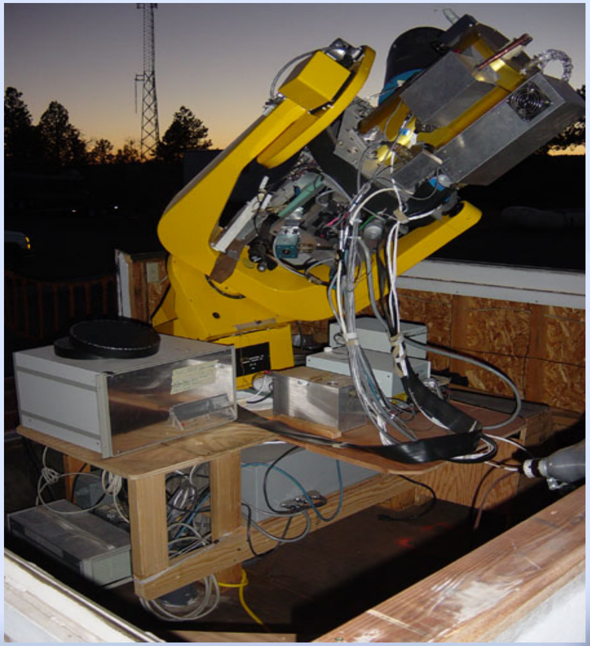


For full moon with zero phase angle
(*Opt. Eng., Vol.38, No.10, pp1763-1764*)

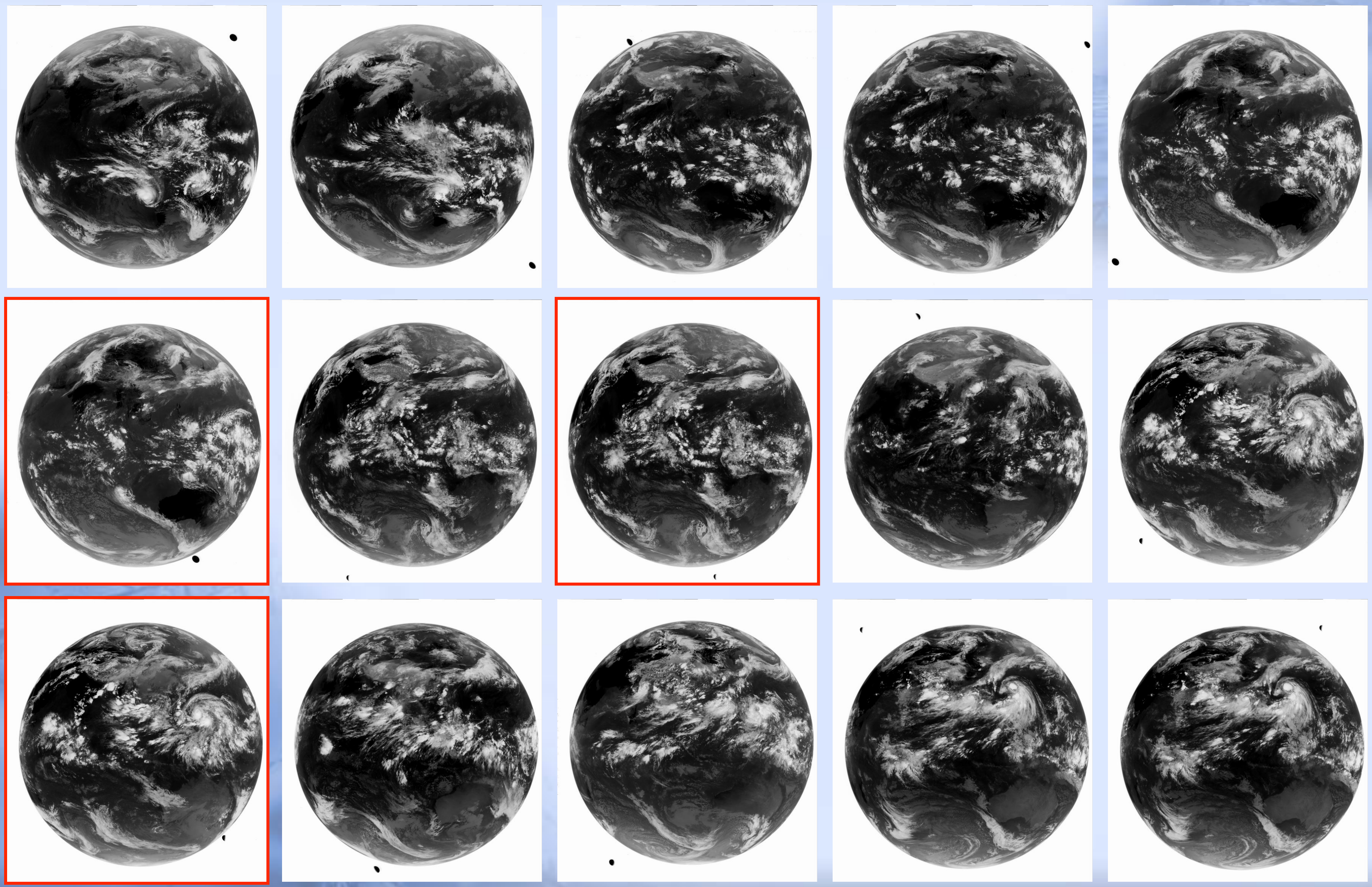
$$L_{emitted} = \varepsilon(\lambda) L^{bb}(\lambda, 390\ \mathrm{K})$$

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.

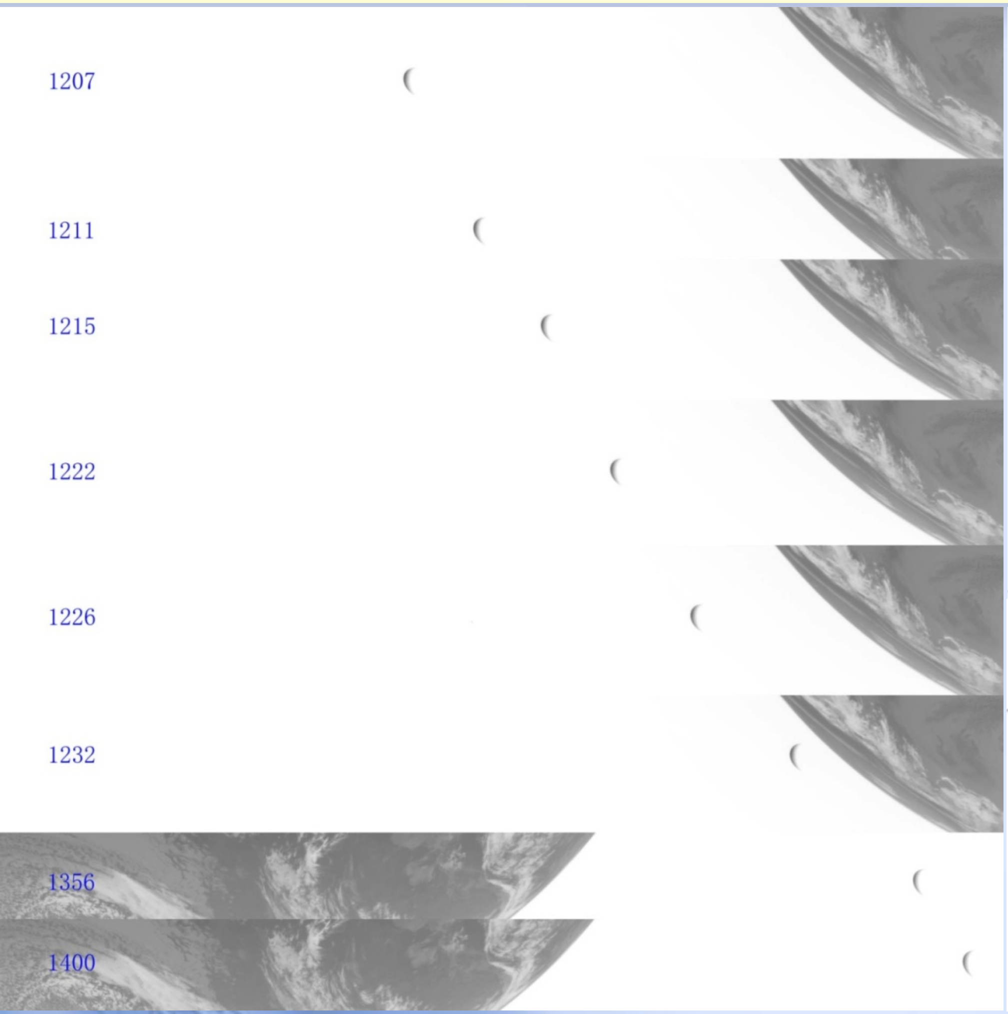
Lunar Obs. on ground: RObotic Lunar Observatory (ROLO) Project

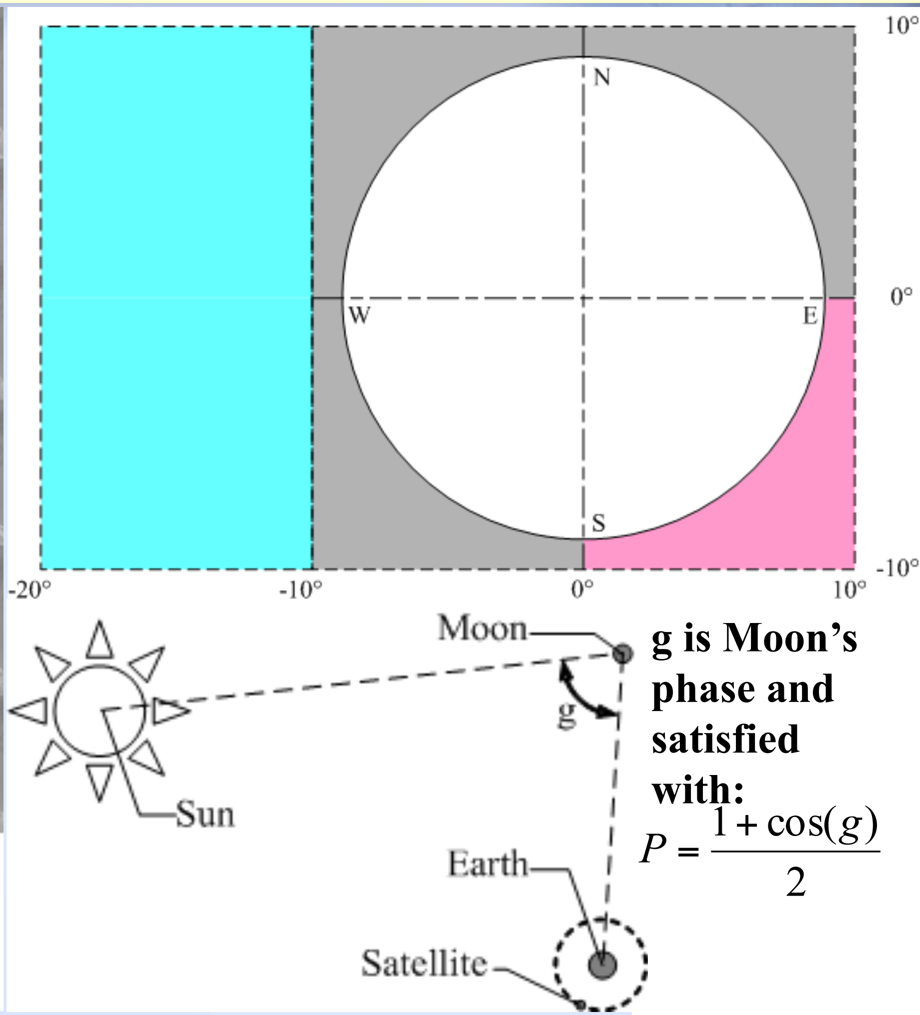


Moon's position distribution for LC in TEBs (Examples as for FY-2E)



Continuous Moon Observations with area-scanning mode of FY-2F in Apr. 16, 2012





g is Moon's phase and satisfied with:

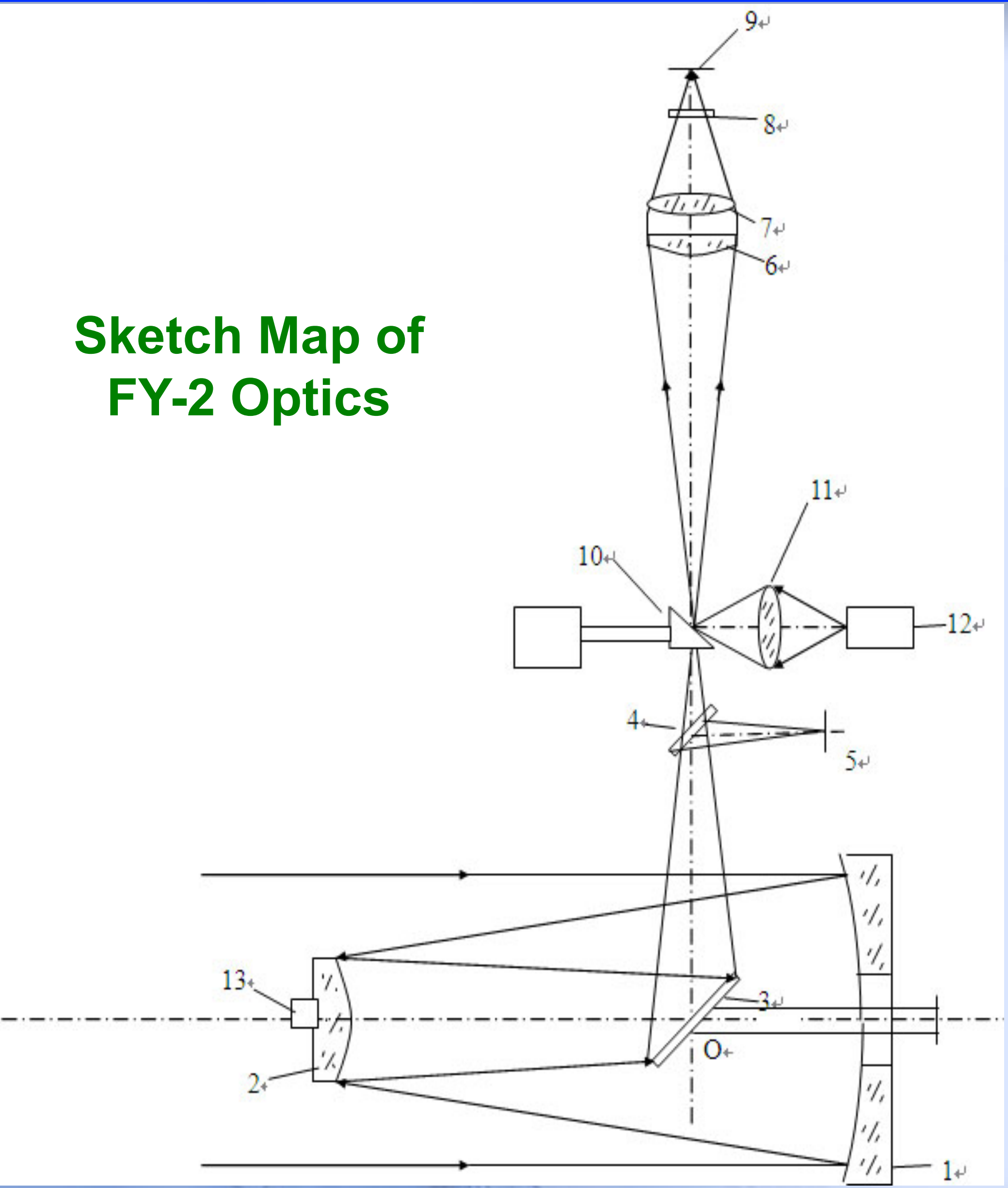
$$P = \frac{1 + \cos(g)}{2}$$

Aft. Cps. 5:1, VIS | **Aft. Cps.1:1**

Aft. Cps. 5:1, IR1 | **Aft. Cps.1:1**

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

Sketch Map of FY-2 Optics

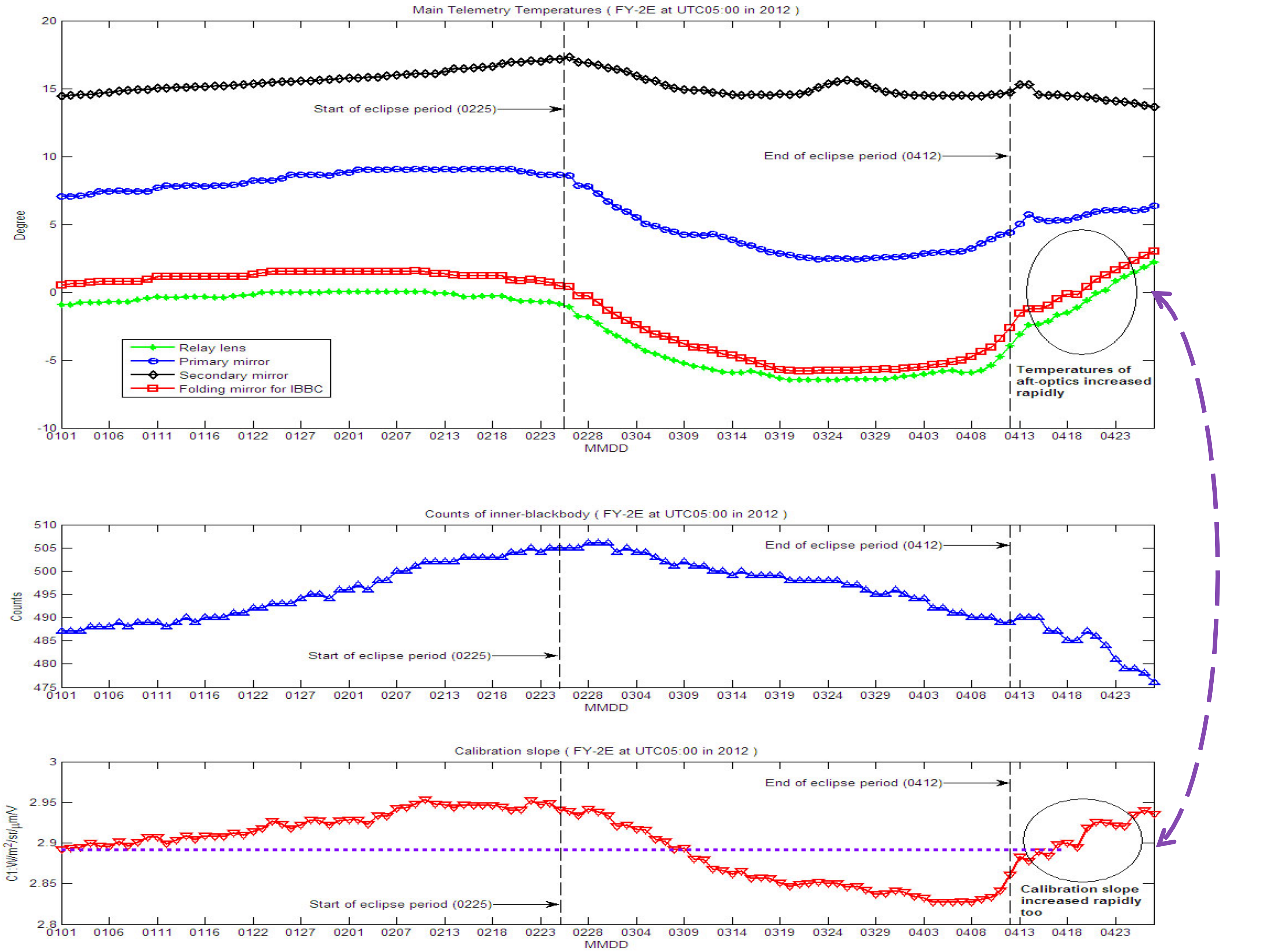


Main Optical Components
1: Primary Mirror
2: Secondary Mirror
6/7: Relay lens
10: Mirror for Cal.
12: Inner-Blackbody

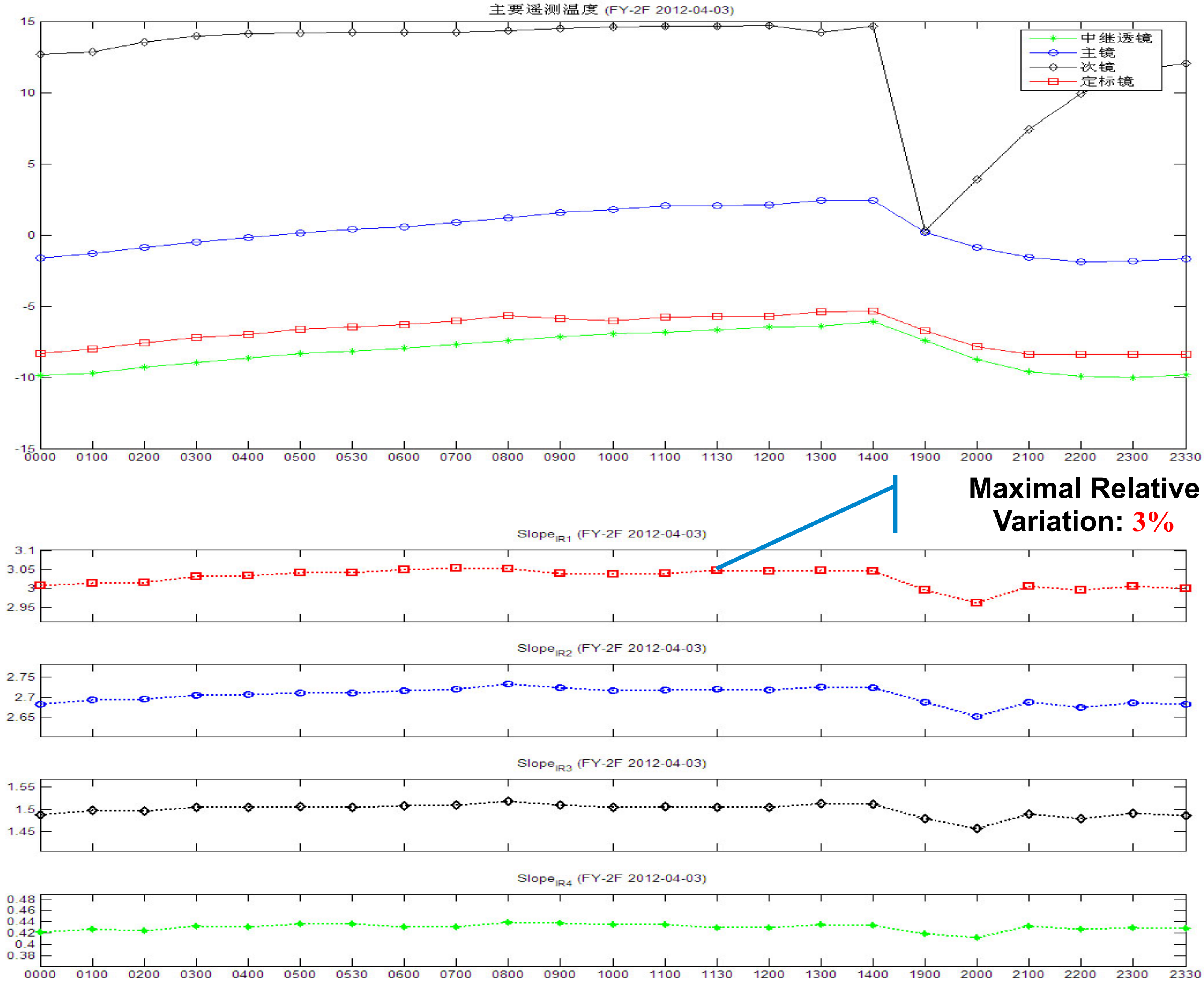
Main Challengers for IBBC of FY-2 satellite

- 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.

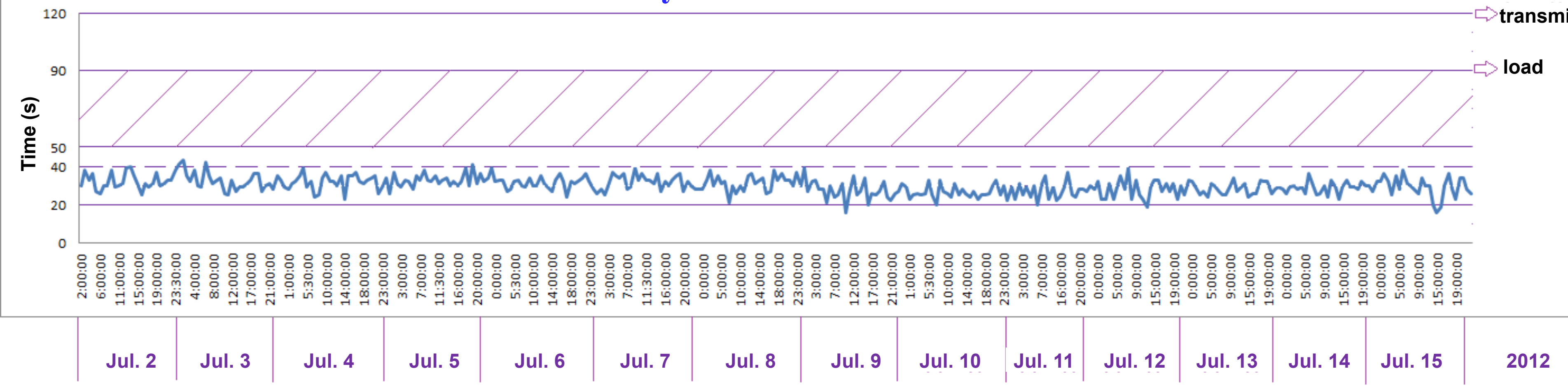
IBBC results for FY-2E between January 1 and April 27, 2012



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



Timeliness analysis for CIBLE in FY-2 satellites

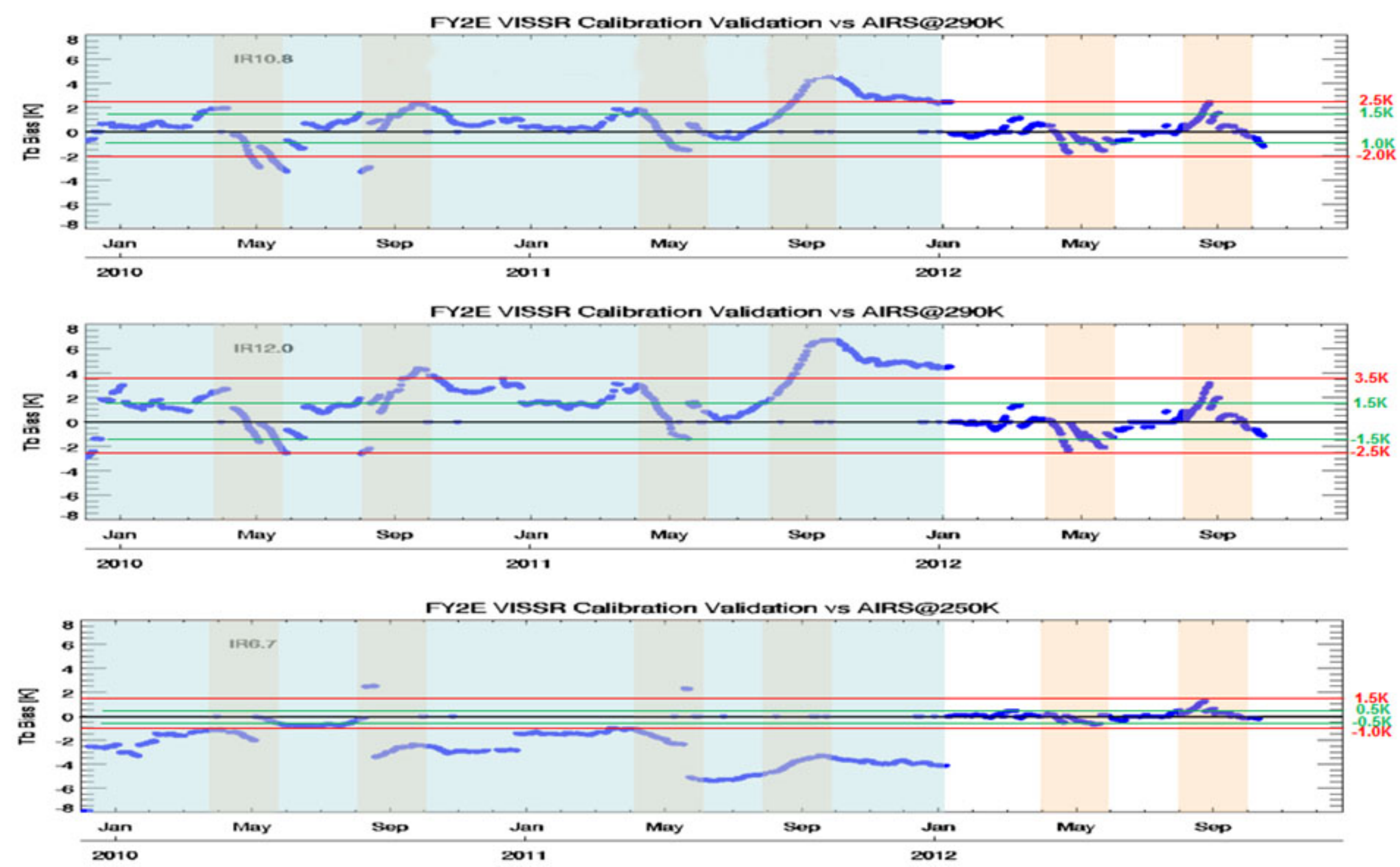


ΔT(Processing time for CIBLE): Min=16s, Max=43s

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

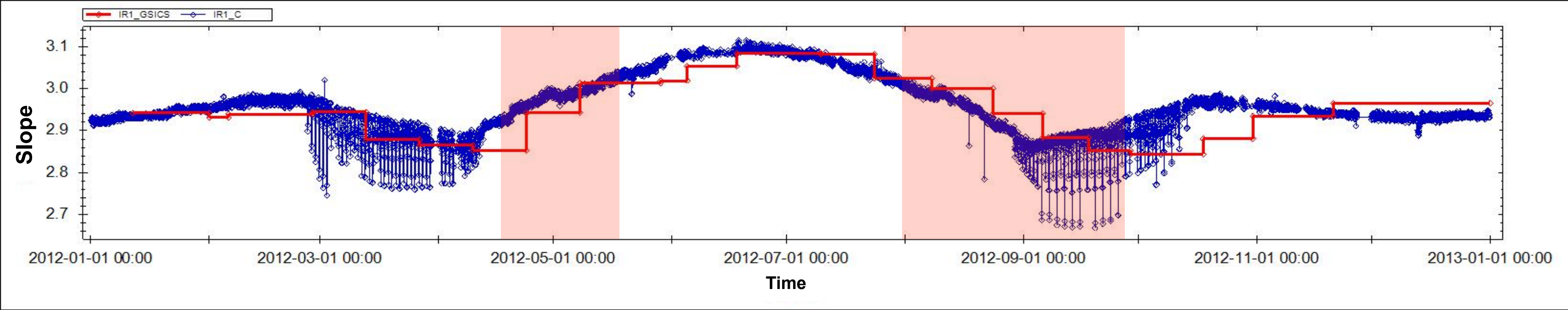
Overview the Working Performance of CIBLE

FY-2E Satellite Operational Calibration Accuracy Monitoring

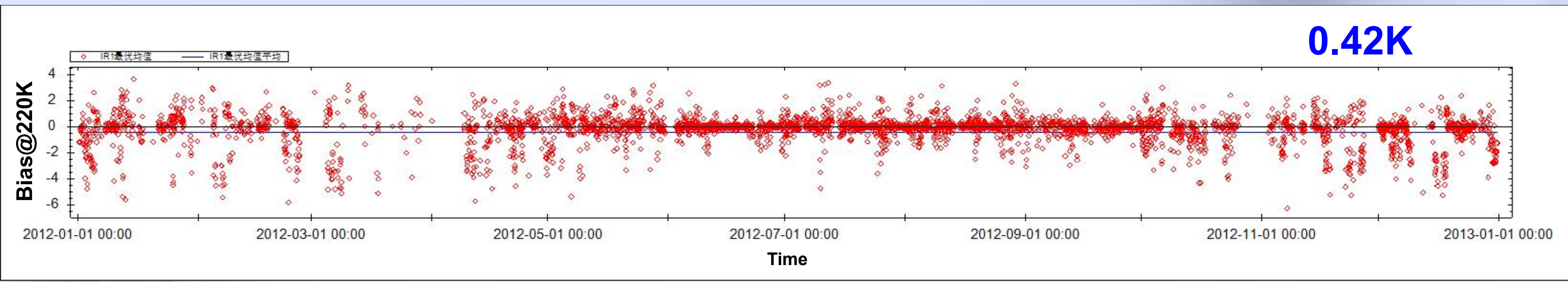


Cross-Calibration with AVHRR/HIRS

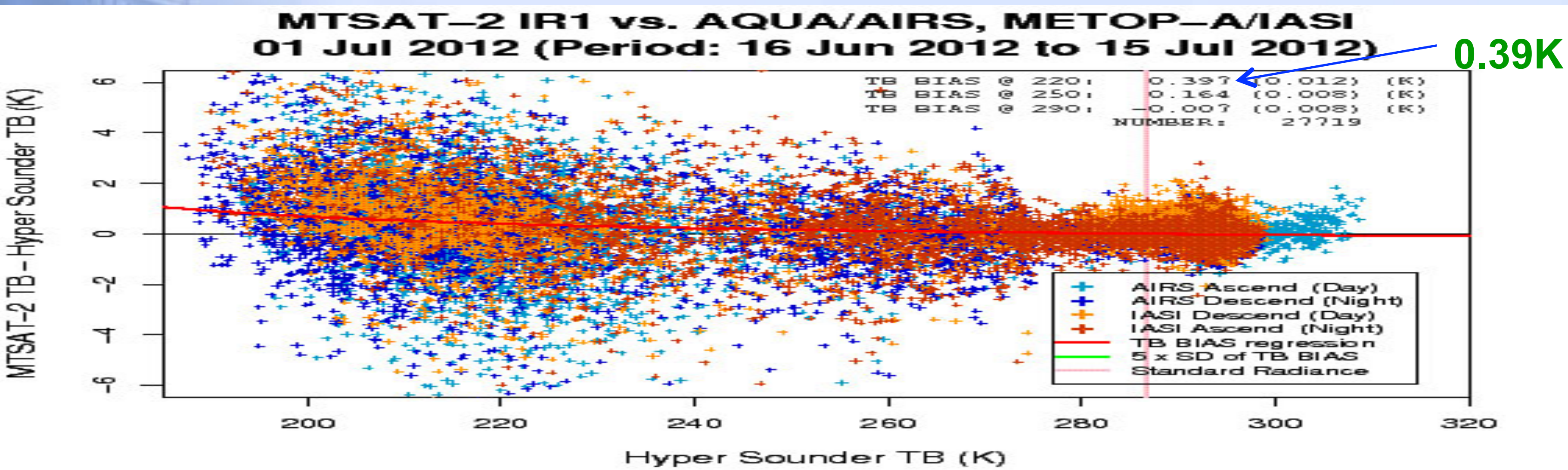
Cross-Calibration with IASI Recommended by GSICS

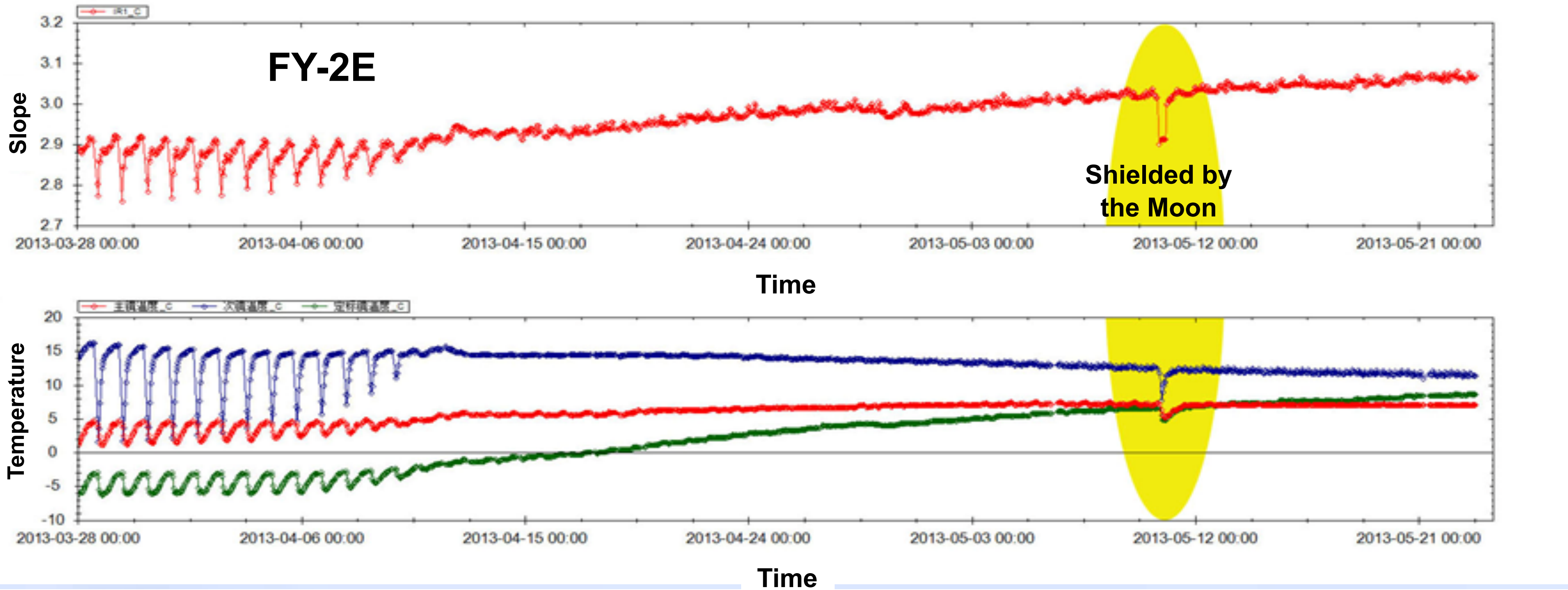


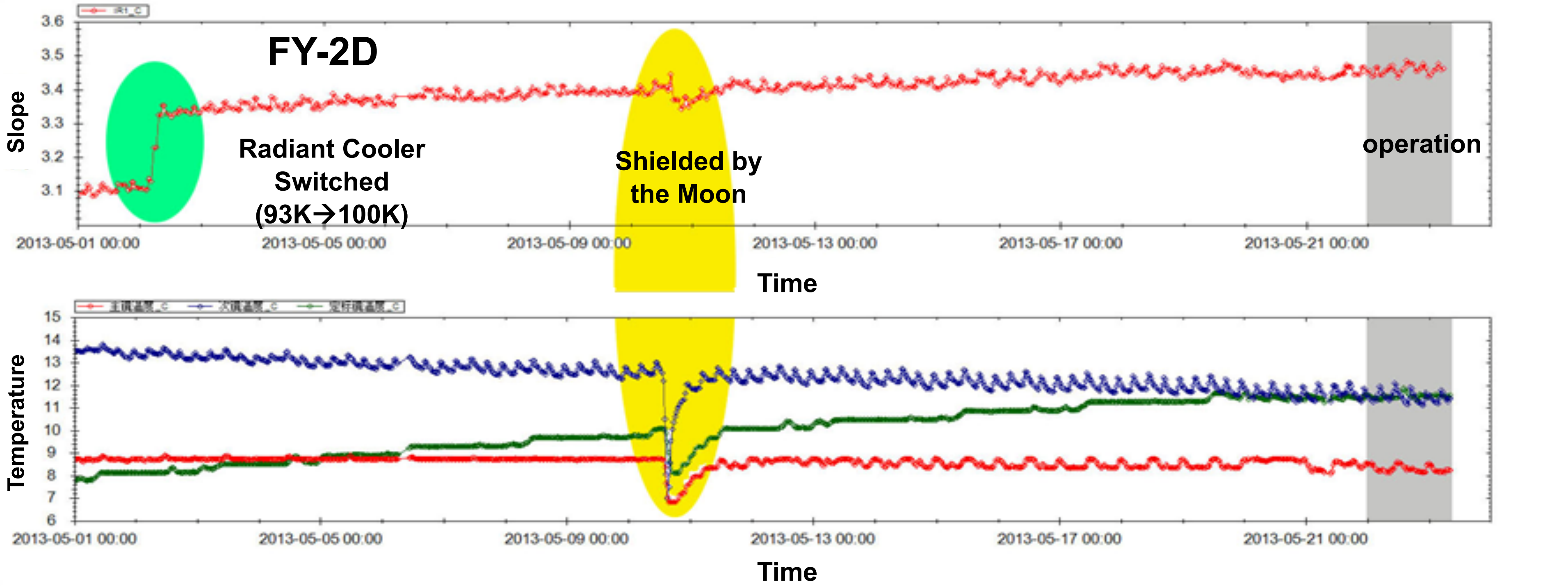
Calibration slope comparison between CIBLE and O.C. in IR1 band during 2012

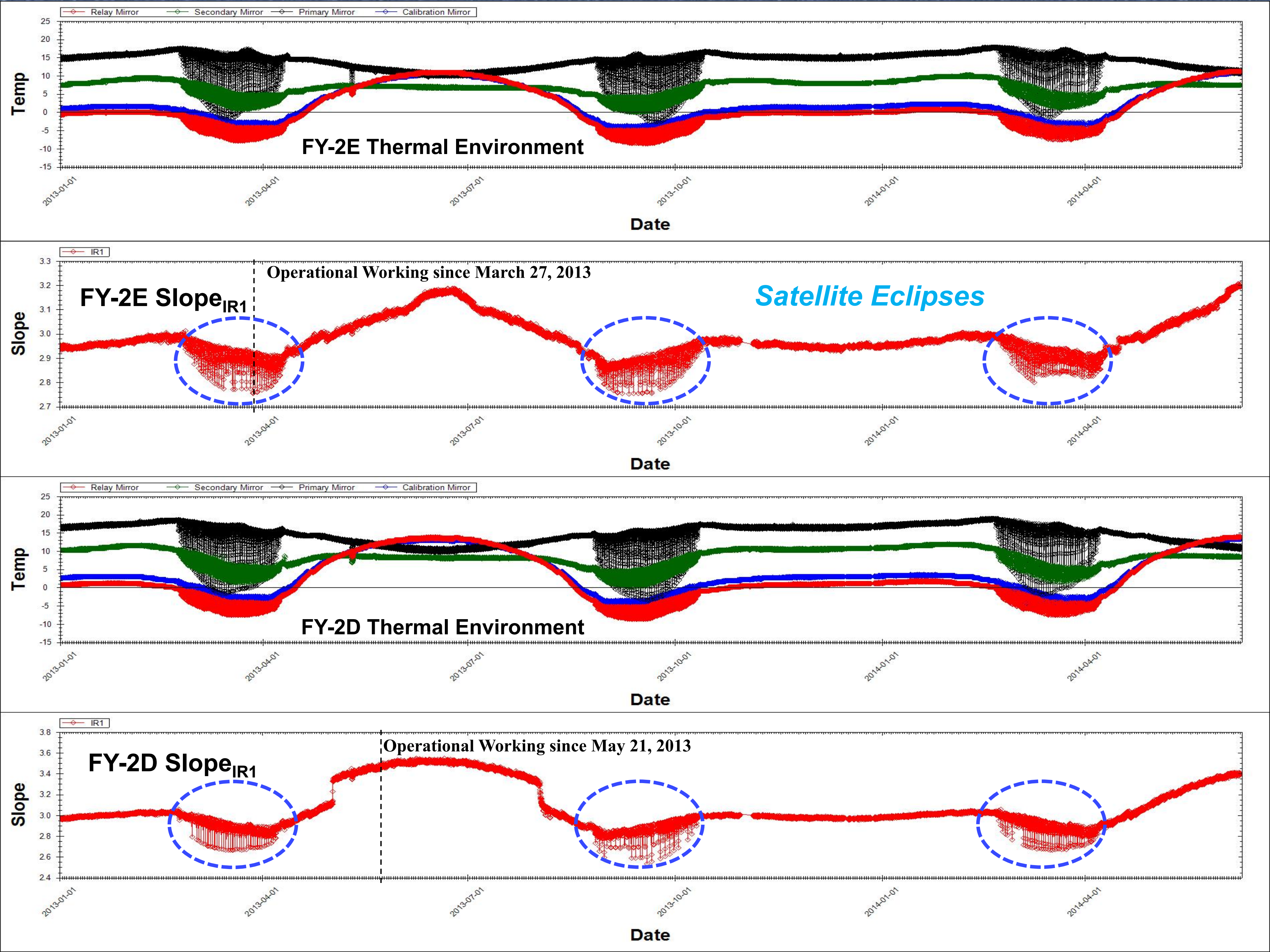


Analysis of CIBLE's accuracy in IR1 band during 2012 for FY-2E

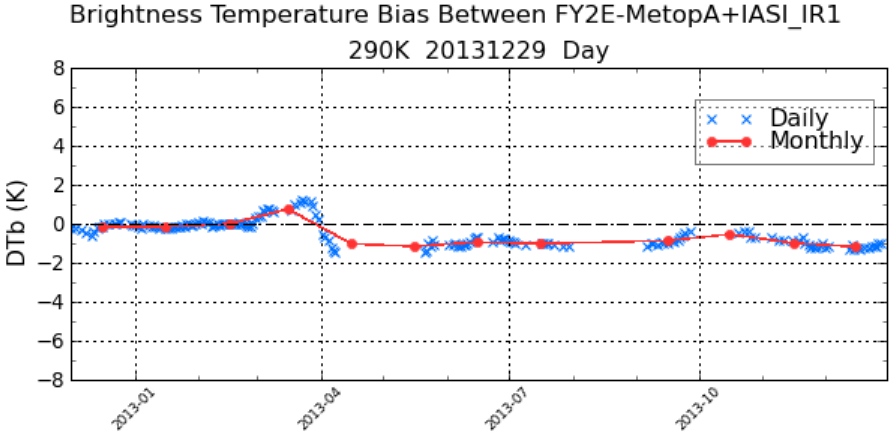


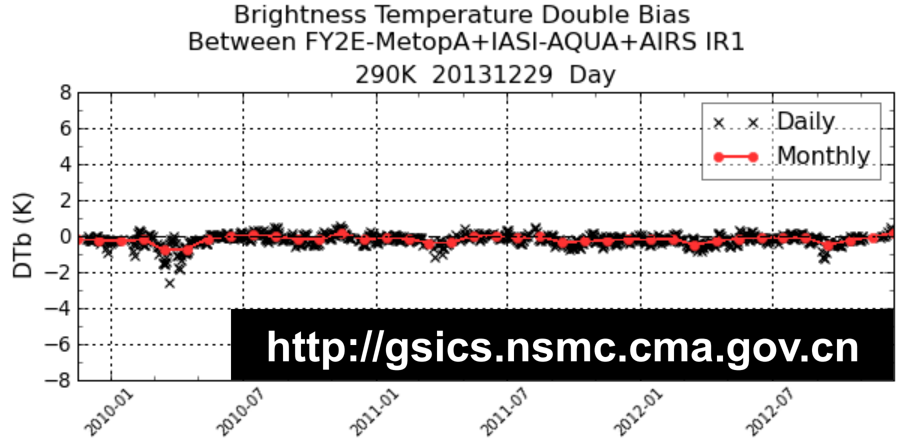

FY-2E
Slope
Shielded by
the Moon
Time
Temperature
Time
2013-03-28 00:00
2013-04-06 00:00
2013-04-15 00:00
2013-04-24 00:00
2013-05-03 00:00
2013-05-12 00:00
2013-05-21 00:00

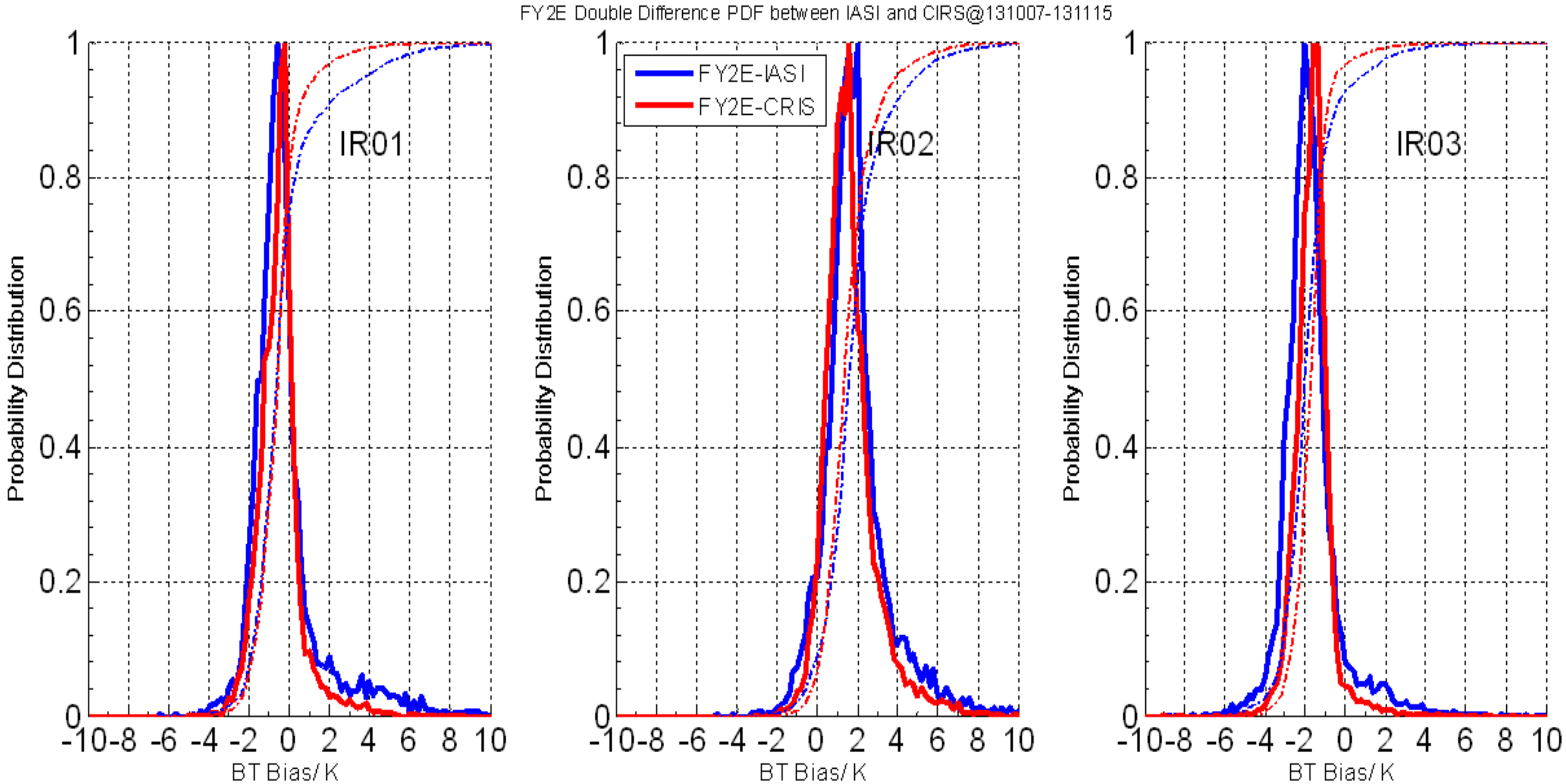

FY-2D
Slope
Radiant Cooler
Switched
(93K→100K)
Shielded by
the Moon
operation
Time
Temperature
Time
2013-05-01 00:00
2013-05-05 00:00
2013-05-09 00:00
2013-05-13 00:00
2013-05-17 00:00
2013-05-21 00:00



Relay Mirror
Secondary Mirror
Primary Mirror
Calibration Mirror
Temp
FY-2E Thermal Environment
Date
IR1
Slope
Operational Working since March 27, 2013
FY-2E Slope$_{IR1}$
Satellite Eclipses
Date
Relay Mirror
Secondary Mirror
Primary Mirror
Calibration Mirror
Temp
FY-2D Thermal Environment
Date
IR1
Slope
Operational Working since May 21, 2013
FY-2D Slope$_{IR1}$
Date





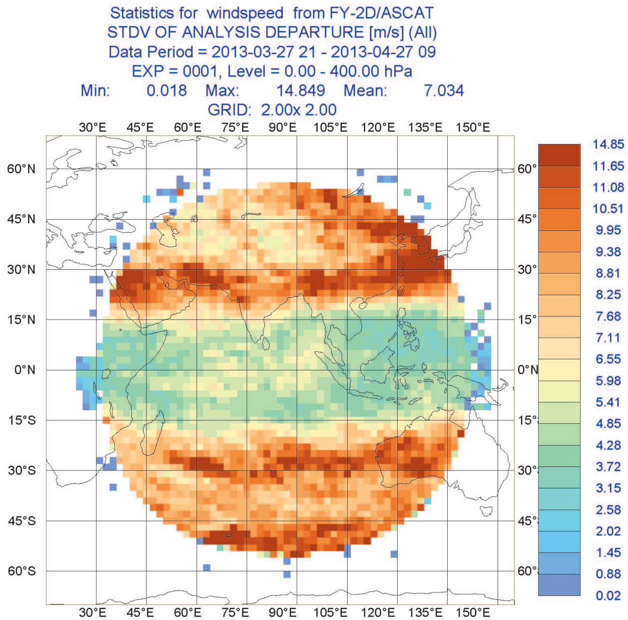


***CrIS* as reference, IR1:-0.5K@290K**

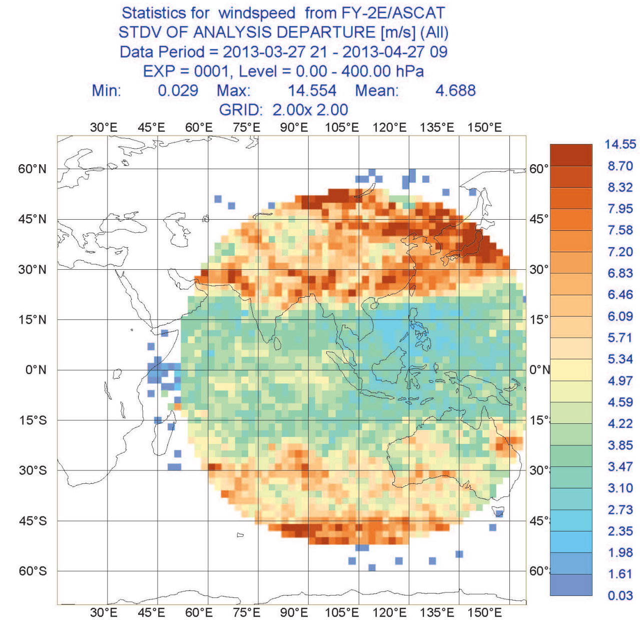
CIBLE's Benefit to FY-2D/E AMV Products

STDV(AMV) analysis for Water-Vapor band between Mar. 27 and Apr. 27 in 2013

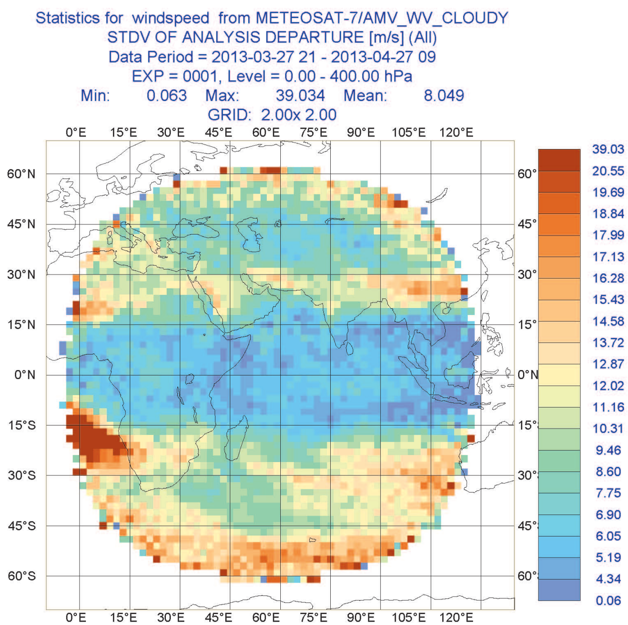
FY-2D
7.034m/s
(GSICS)



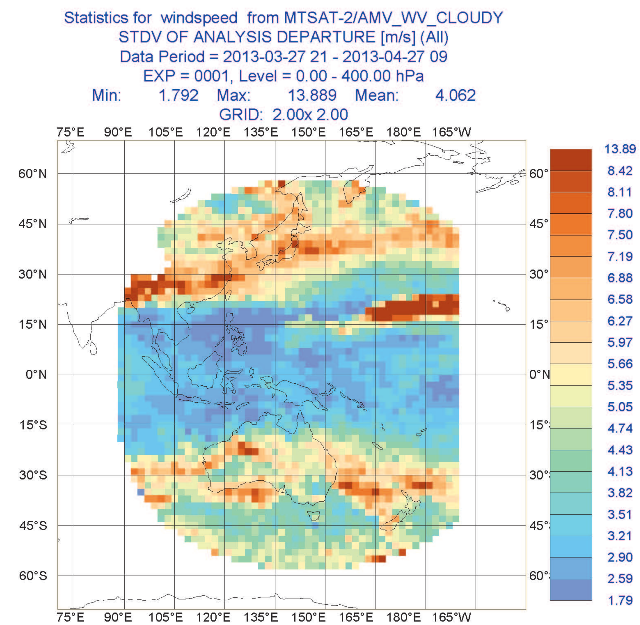
FY-2E
4.688m/s
(CIBLE)



MET7
8.049m/s



MTS2
4.062m/s

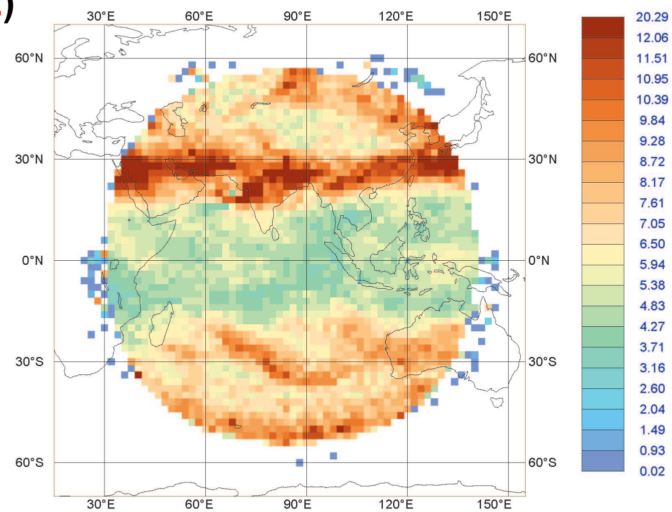


http://www.ecmwf.int/products/forecasts/d/charts/monitoring/satellite/amv/windspeed/

STDV(AMV) analysis for Water-Vapor band between March 6 and April 5 in 2014

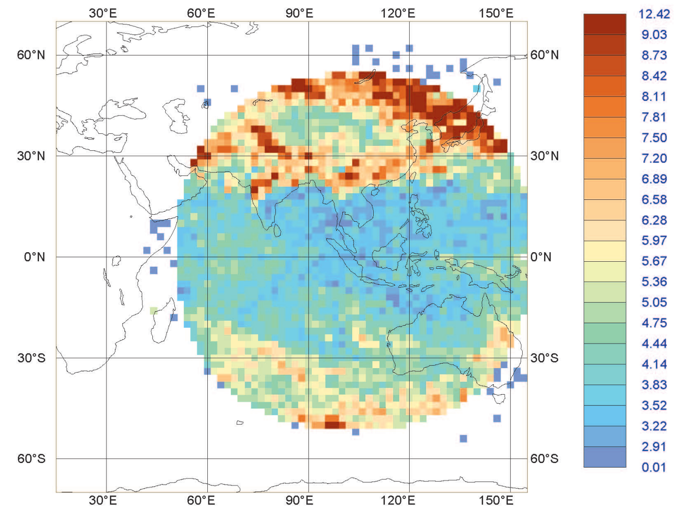
FY-2D
6.499m/s
(CIBLE)

STATISTICS FOR WINDSPEED FROM FROM FY-2D/ASCAT
STDV OF ANALYSIS DEPARTURE [M/S] (ALL)
DATA PERIOD = 2014-03-06 21 - 2014-04-05 09
EXP = 0001, LEVEL = 0.00 - 400.00 HPA
Min: 0.020 Max: 20.288 Mean: 6.499
GRID: 2.00x 2.00



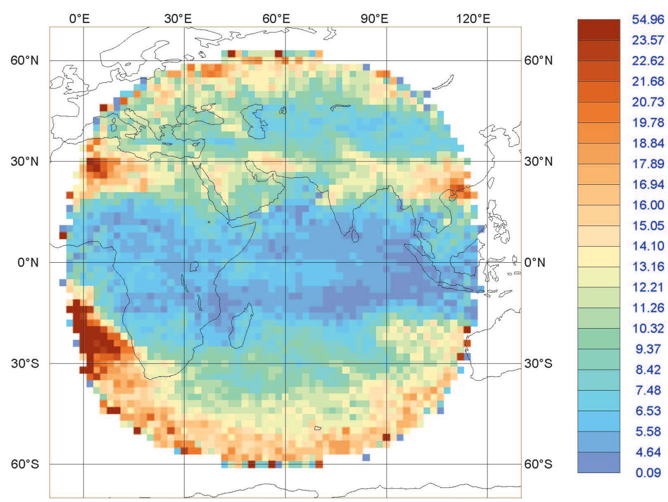
FY-2E
4.596m/s
(CIBLE)

STATISTICS FOR WINDSPEED FROM FROM FY-2E/ASCAT
STDV OF ANALYSIS DEPARTURE [M/S] (ALL)
DATA PERIOD = 2014-03-06 21 - 2014-04-05 09
EXP = 0001, LEVEL = 0.00 - 400.00 HPA
Min: 0.011 Max: 12.418 Mean: 4.596
GRID: 2.00x 2.00



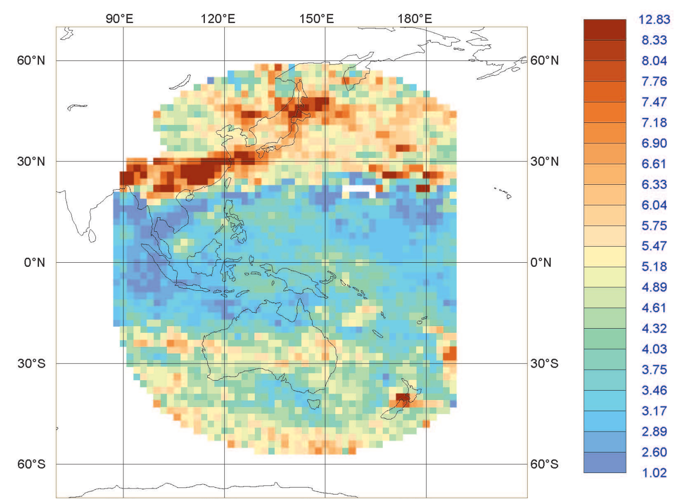
MET7
7.048m/s

STATISTICS FOR WINDSPEED FROM FROM METEOSAT-7/AMV_WV_CLOUDY
STDV OF ANALYSIS DEPARTURE [M/S] (ALL)
DATA PERIOD = 2014-03-06 21 - 2014-04-05 09
EXP = 0001, LEVEL = 0.00 - 400.00 HPA
Min: 0.089 Max: 54.957 Mean: 7.948
GRID: 2.00x 2.00

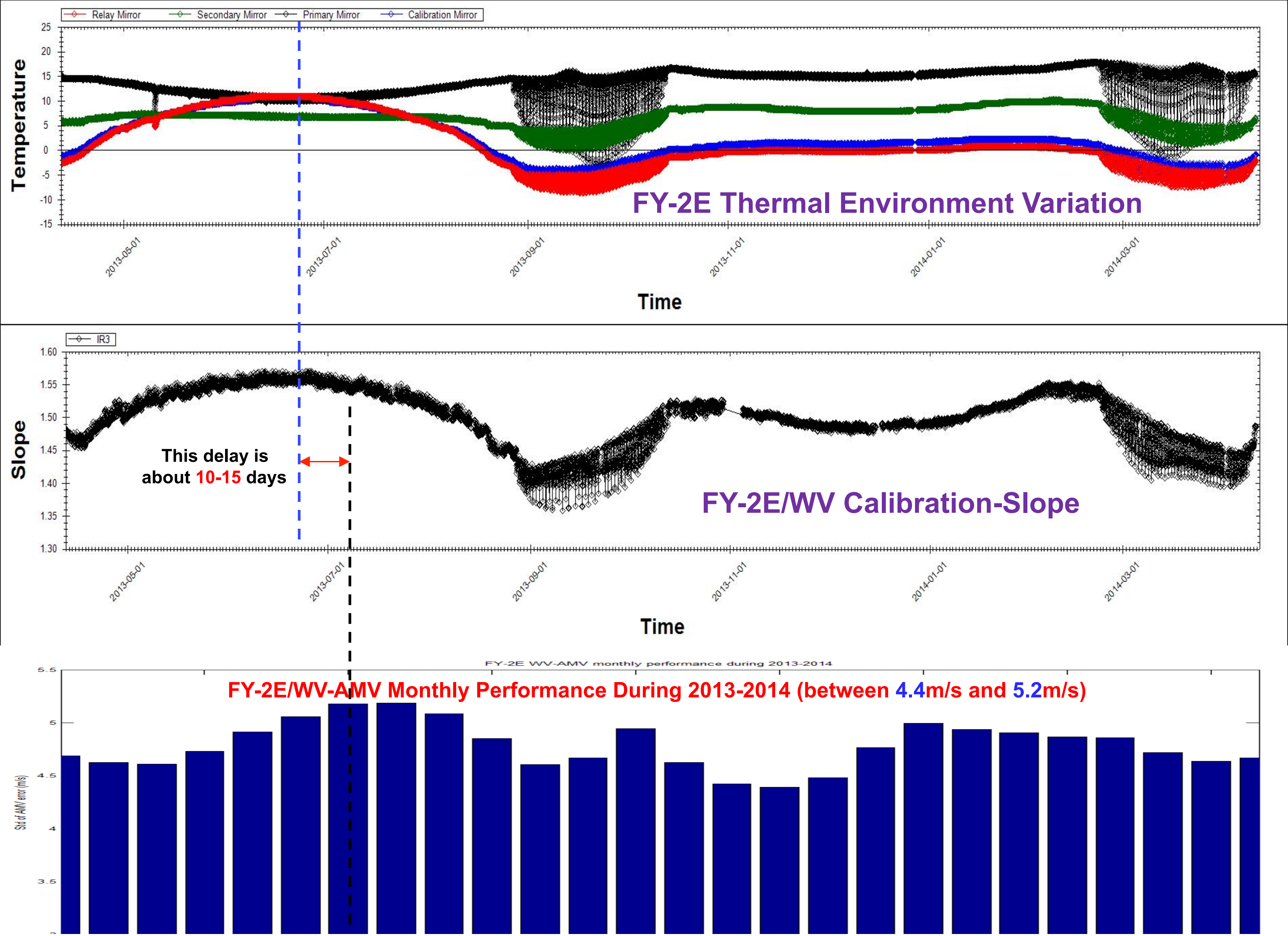


MTS2
4.106m/s

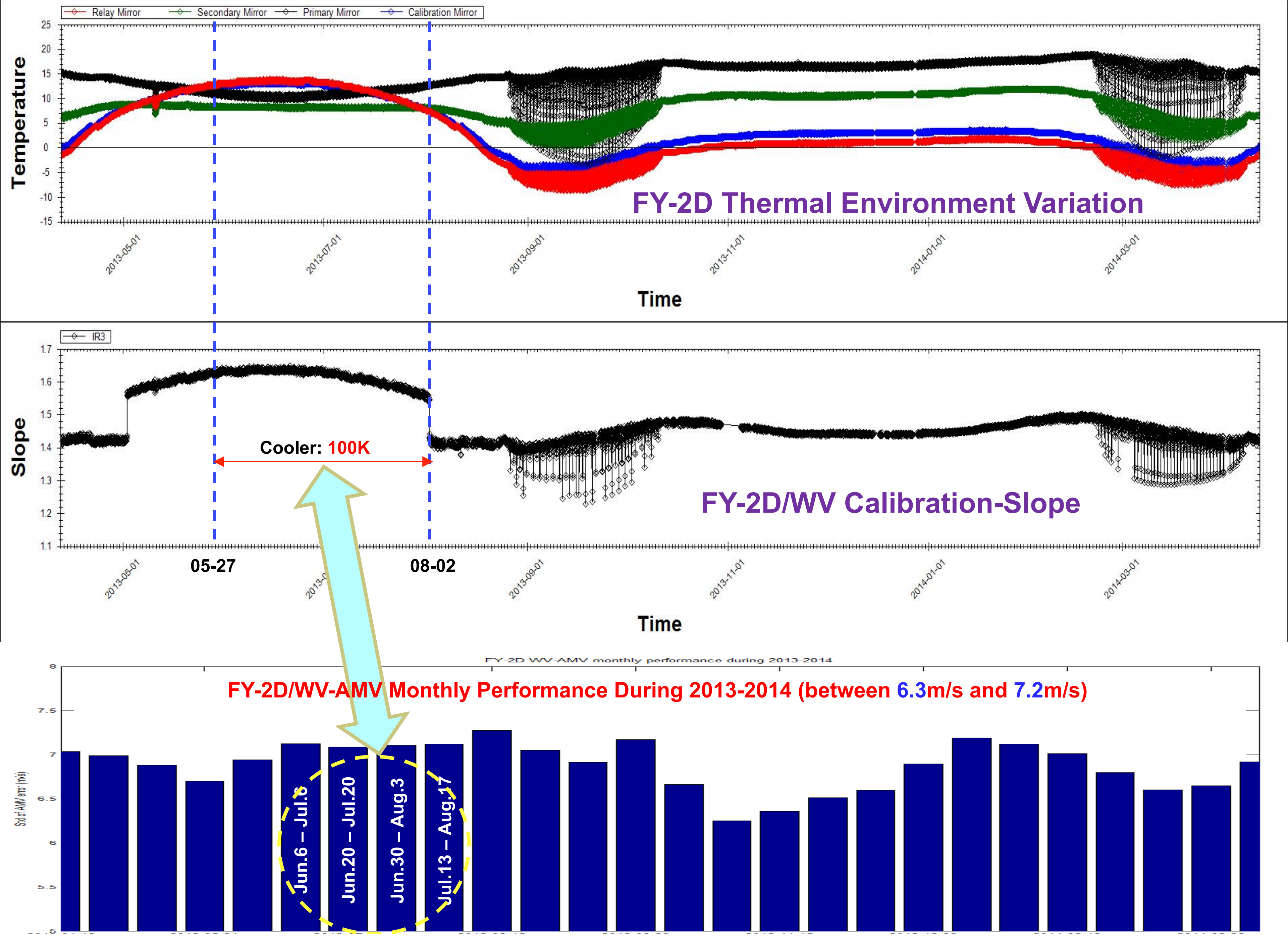
STATISTICS FOR WINDSPEED FROM FROM MTSAT-2/AMV_WV_CLOUDY
STDV OF ANALYSIS DEPARTURE [M/S] (ALL)
DATA PERIOD = 2014-03-06 21 - 2014-04-05 09
EXP = 0001, LEVEL = 0.00 - 400.00 HPA
Min: 1.019 Max: 12.835 Mean: 4.106
GRID: 2.00x 2.00



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

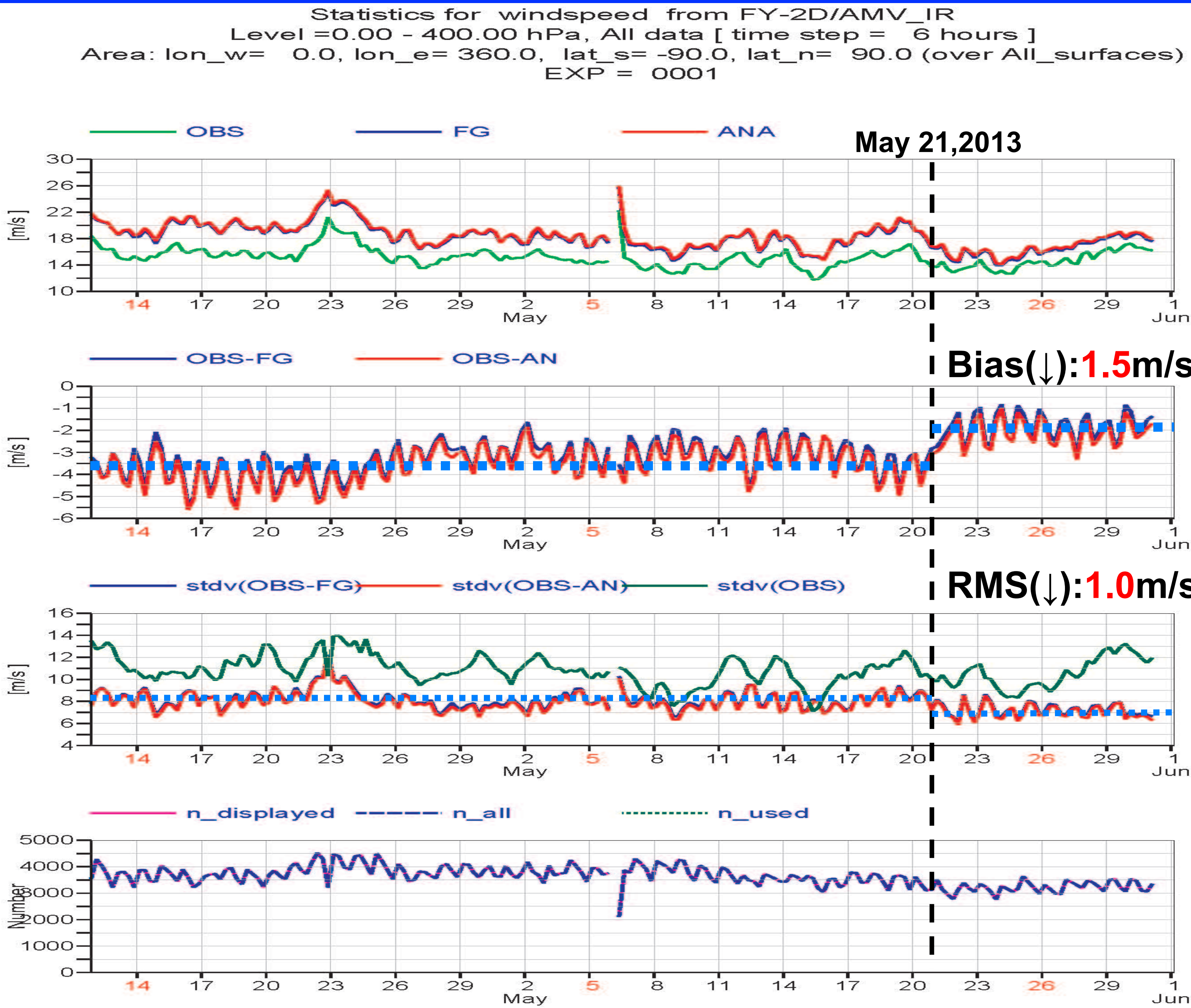


http://www.ecmwf.int/products/forecasts/d/charts/monitoring/satellite/amv/windspeed/

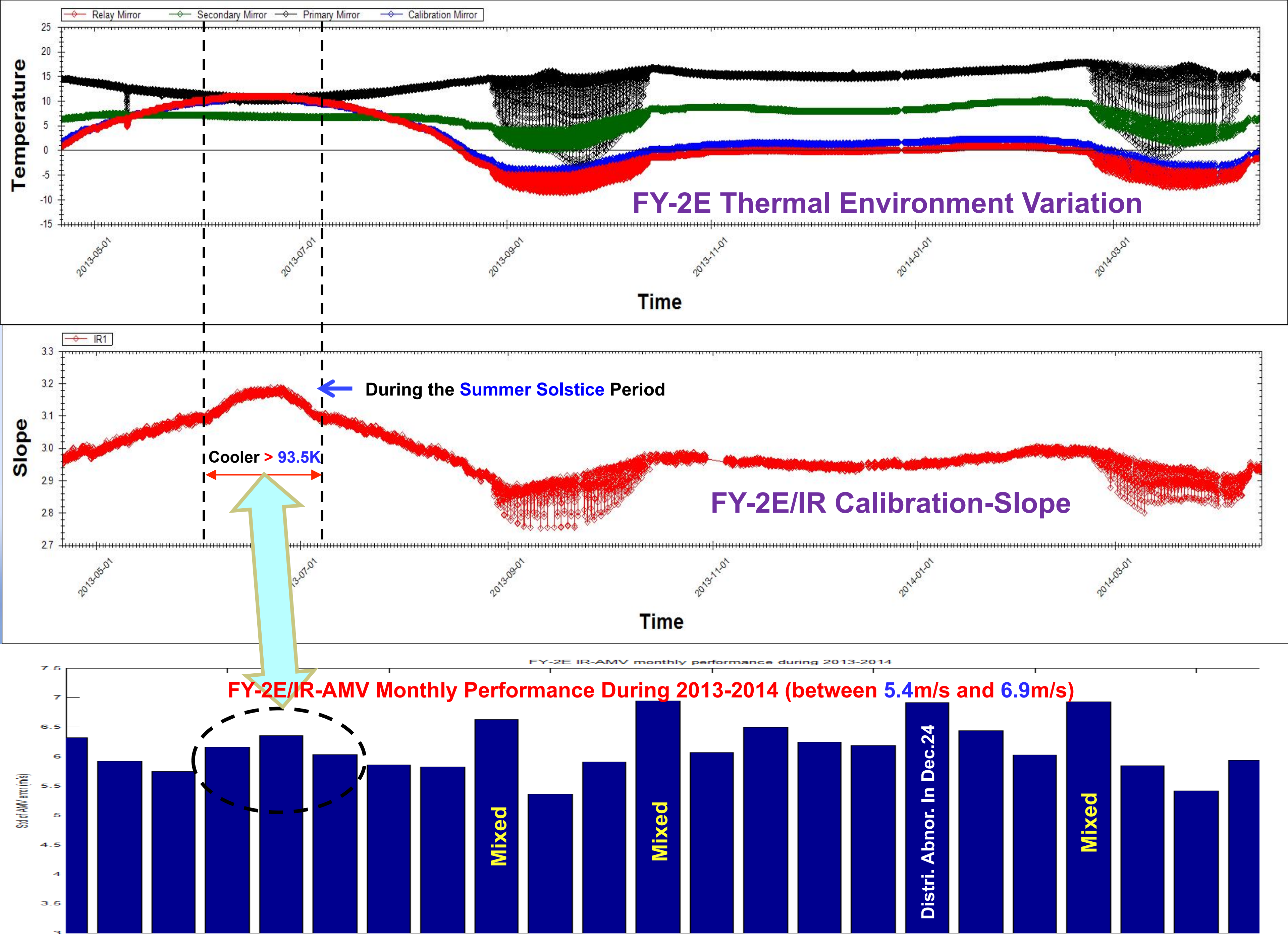


http://www.ecmwf.int/products/forecasts/d/charts/monitoring/satellite/amv/windspeed/

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/



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

Conclusion

- The CIBLE method has been independently developed 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 satellite .

- 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.

- By using the latest CIBLE outcomes, the performances of AMV has also been greatly improved. Particularly, it is validated by ECMWF that the RMSE of WV-AMV for FY-2E satellite remains 4-5 m/s and the bias of IR-AMV for FY-2D satellite has been decreased by about 1.5 m/s after using CIBLE approaches.

Thanks for your attention!