VIIRS Radiometric Performance Improvements for Operations

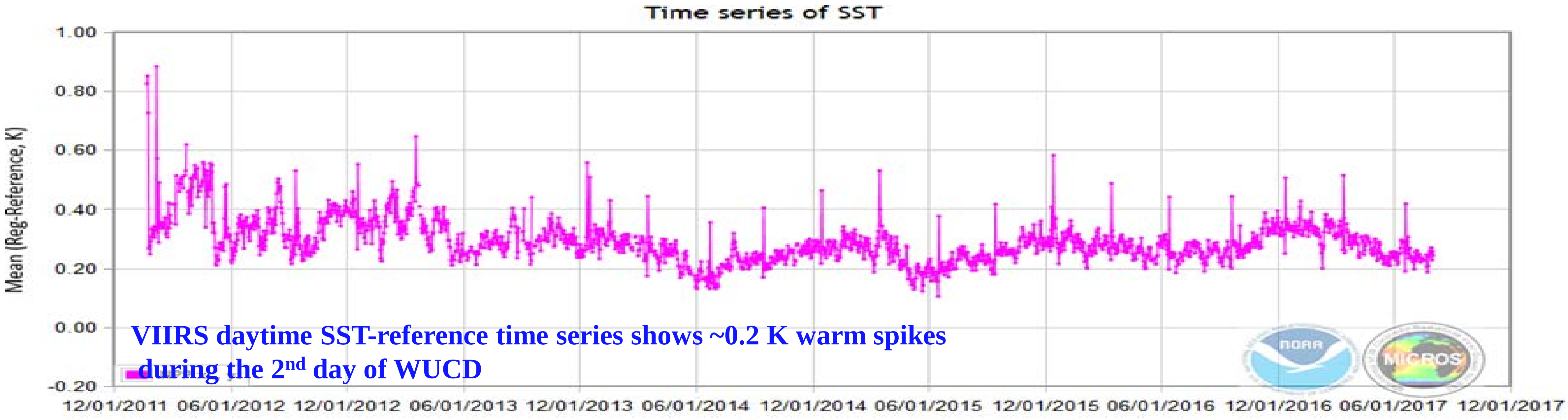
1) Thermal Emissive Band (TEB) improvements- WUCD correction (W. Wang)

2) Kalman Filter-based Predictive Model to Support Near Realtime VIIRS RSB SDR Product (X. Shao)

STAR JPSS Annual Science Meeting, 14-18 August, 2017

Progress in TEB Calibration & Anomaly Resolution

- S-NPP VIIRS TEB calibration performs well during nominal operations:
  - Achieved validated maturity on March 19, 2014
  - Quarterly onboard blackbody warm-up-cool-down (WUCD) are used to characterize calibration offset and nonlinearity changes
- VIIRS SST product is consistent with reference, except for long standing anomalies during WUCD.

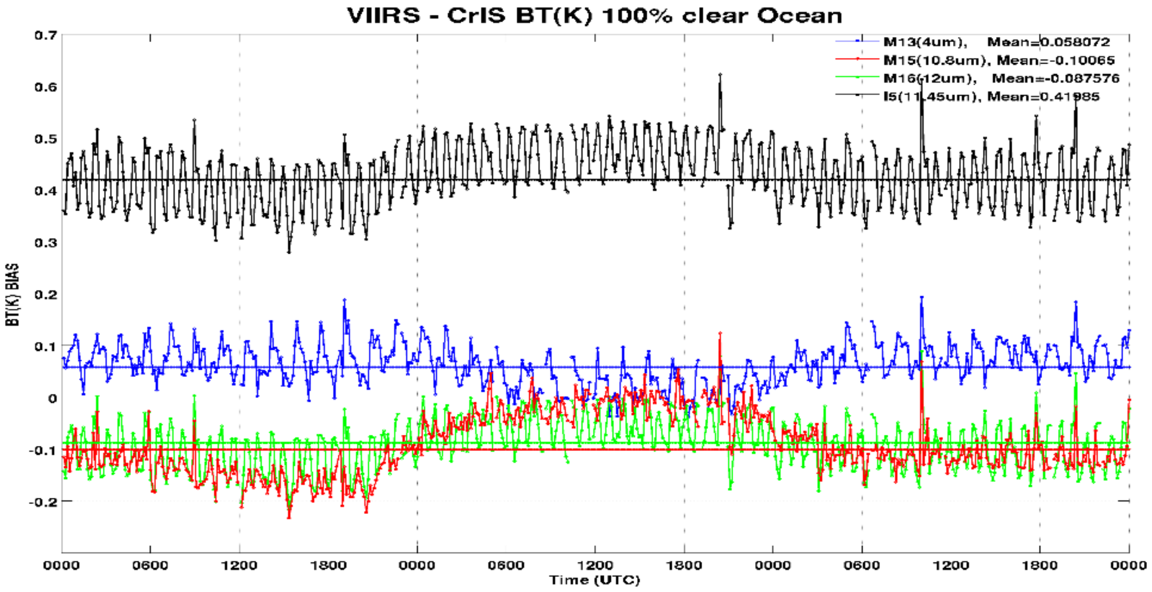


TEB Calibration Bias during WUCD

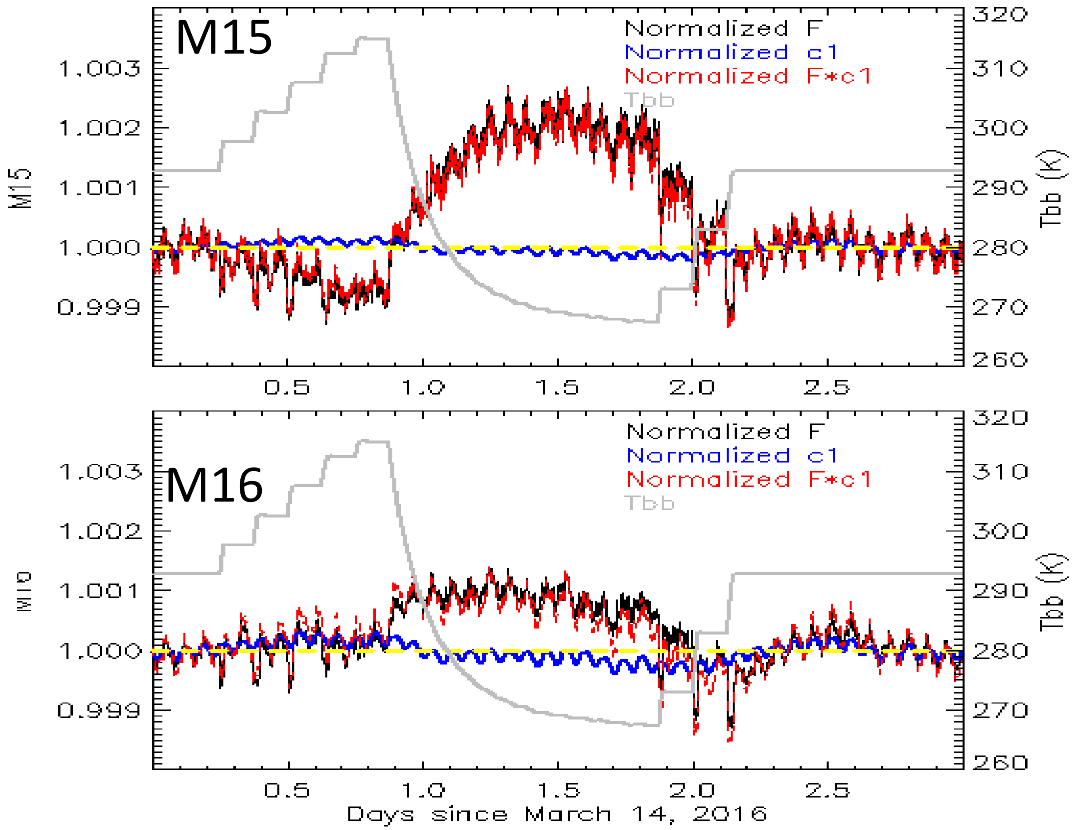
- SST WUCD anomaly is mainly caused by calibration biases in M15/M16 and further amplified by the SST algorithm (Cao et al. 2017)

M15 WUCD bias: 0.1 K
M16 WUCD bias: 0.05 K

WUCD biases were also observed in other TEB bands, with different magnitude/patterns



Courtesy of Dr. Jun Li (University of Wisconsin Team)

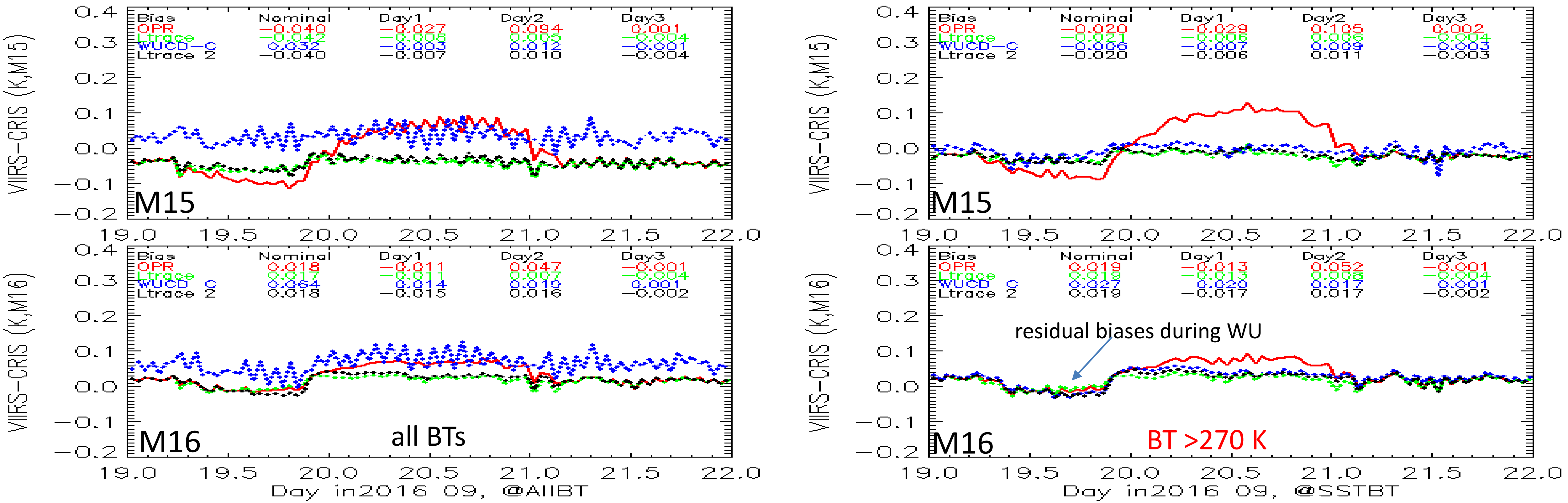


F-Factor anomalies during WUCD

NOAA STAR Algorithm (Cao et al. 2017)
for TEB WUCD calibration bias correction

- **VIIRS TEB WUCD biases are due to a flawed theoretical assumption in the TEB calibration equation**
  - The assumption is not working well during the WUCD event when the blackbody is unstable
- **Three correction methods were developed, implemented, and validated:**
  - **The Ltrace Method (empirical)**
    - Introduces an additive correction term (Ltrace) to the TEB F-factor equation to reconcile calibration curve changes during WUCD;
    - Localized correction, applying during non-nominal Tbb only.
  - **The WUCD-C Method**
    - Uses WUCD-derived C coefficients for TEB calibration, global correction method
  - **The Ltrace v2 Method (analytical)**
    - Introduces scaling factors to the operational TEB F-factors;
    - Scaling factors are derived from prelaunch and on-orbit WUCD derived C coefficients under nominal and actual BB temperatures;
    - Localized correction, implementation similar to the Ltrace method.
  - All methods are easy to implement operationally.

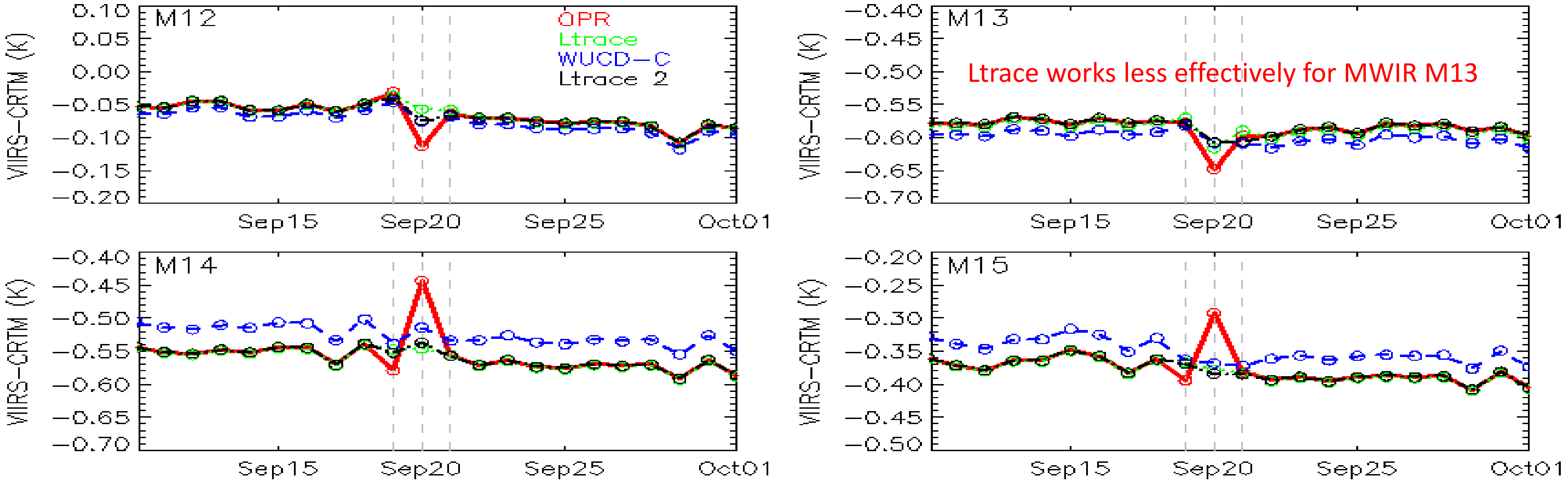
WUCD Bias Correction Method Validations
- Using co-located CrIS observations

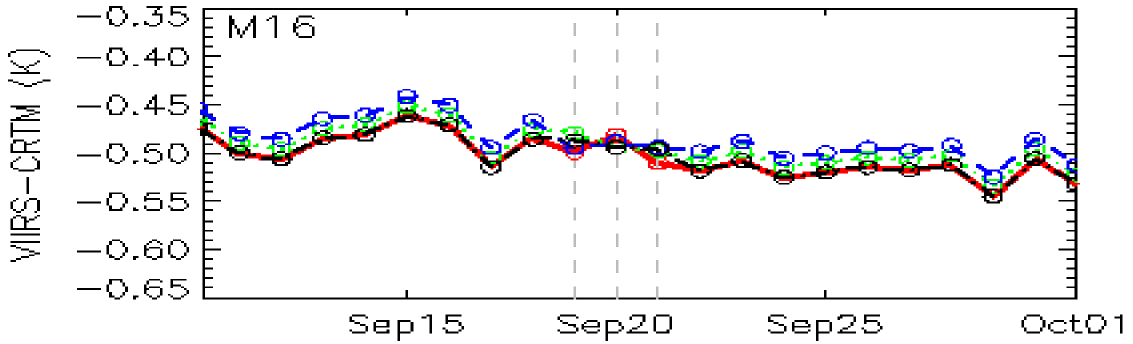


- **The three methods perform well for WUCD bias correction**
  - residual WUCD biases: 0.01 to 0.02 K;
  - **The Ltrace method perform the best, residual bias 0.01 K;**
  - Small under-corrections during the warm-up phase for all methods, require further study;
  - WUCD-C: larger polar to tropical variations observed, require further study.

In collaboration with Dr. Jun Li (University of Wisconsin Team)

WUCD Bias Correction Method Validation
- Using CRTM simulated clear-sky ocean radiances (nighttime)



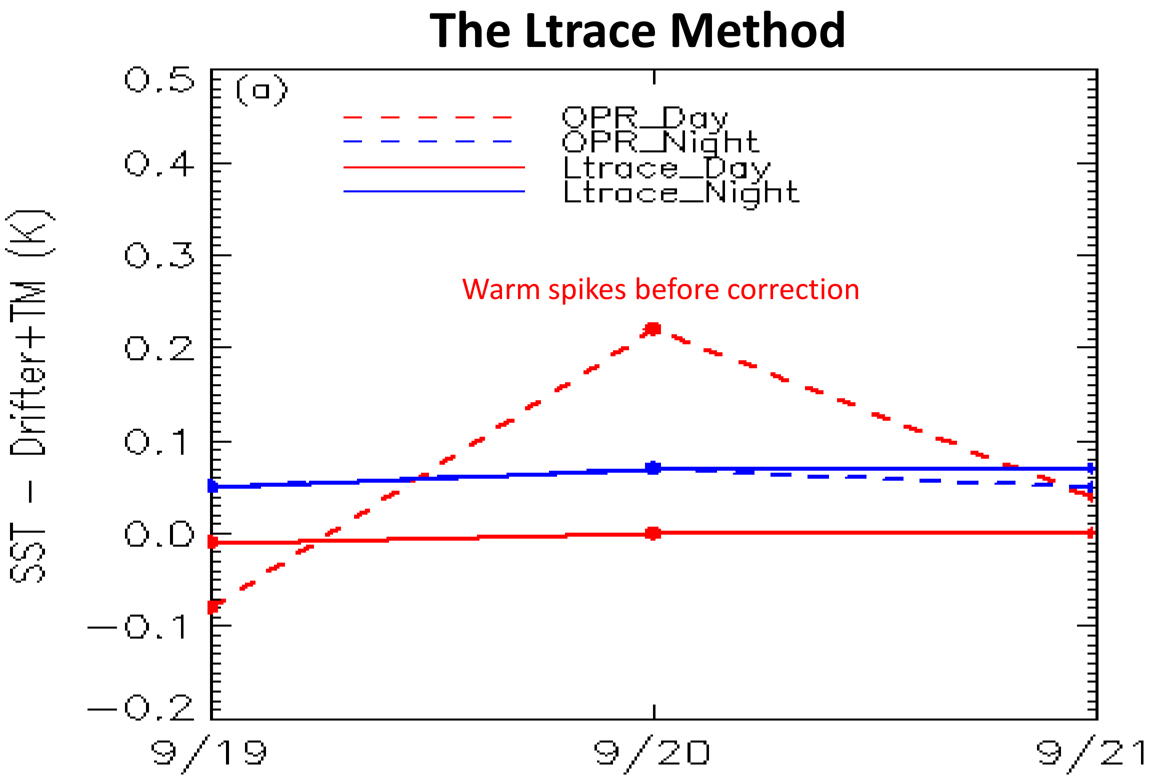


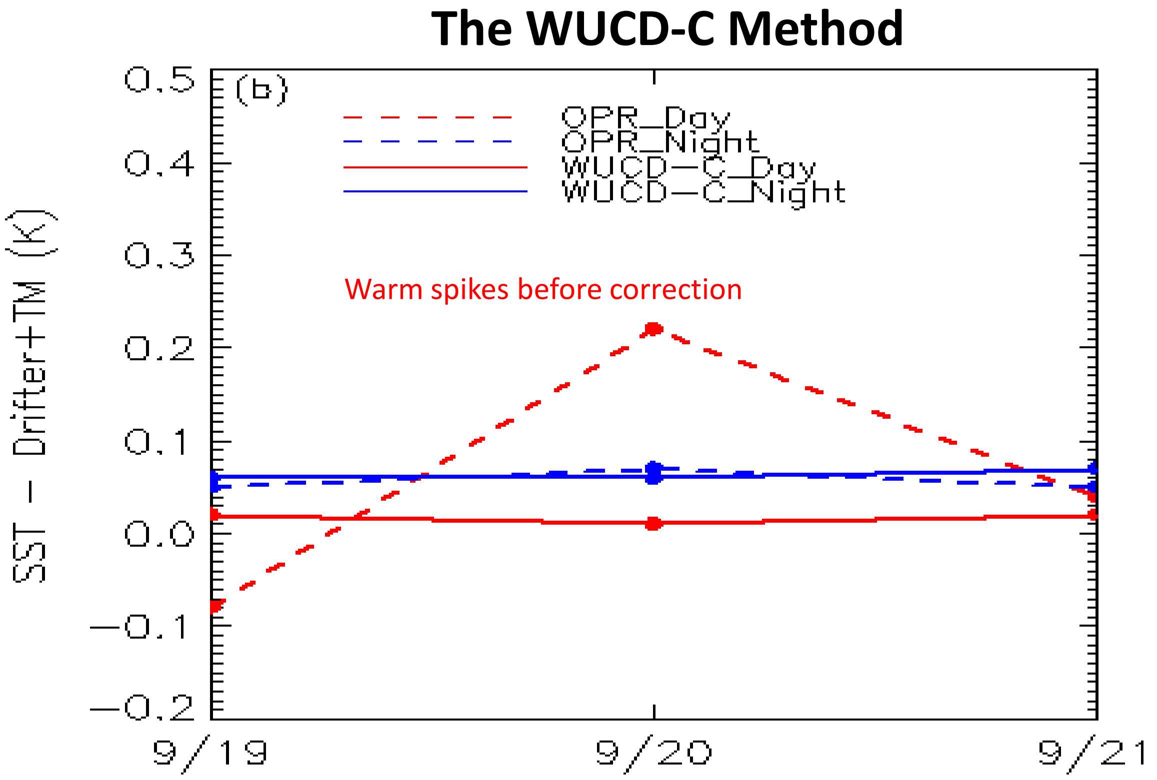
- All three methods perform well to correct WUCD calibration biases for TEB M-bands:

  Ltrace works less effectively for M13
- Consistent with the VIIRS-CrIS results.

In collaboration with Dr. Xingming Liang (STAR ICVS Team)

Impacts on SST Retrieval





- Both the Ltrace and WUCD-C method can effectively remove WUCD anomalies in the SST time series;
- The Ltrace 2 method is also expected to work well.

In collaboration with Dr. Alex Ignatov (NOAA STAR SST team)

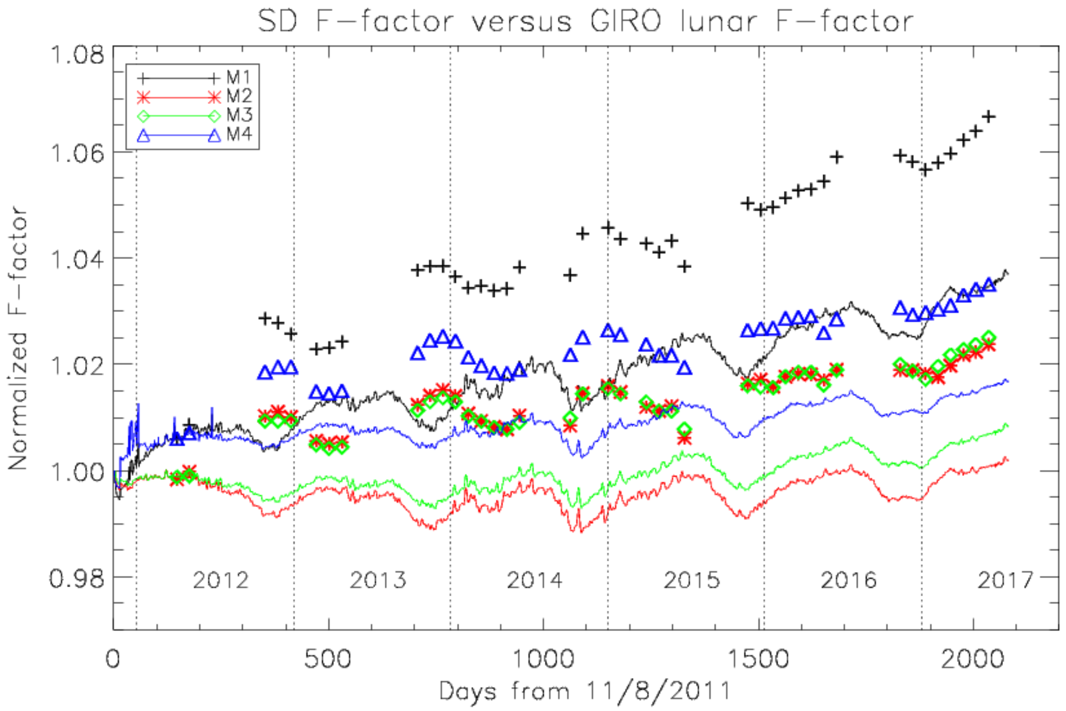
Summary

- Three VIIRS TEB WUCD bias correction methods were developed, implemented, and evaluated:
  - (1) Ltrace; (2)WUCD-C; (3) Ltrace v2.
  - All methods work well in terms of WUCD bias correction;
  - The Ltrace method performs the best for LWIR bands and is the easiest to implement operationally;
  - Further validation and analysis will be conducted for the Ltrace 2 method, especially for MWIR bands WUCD bias correction.

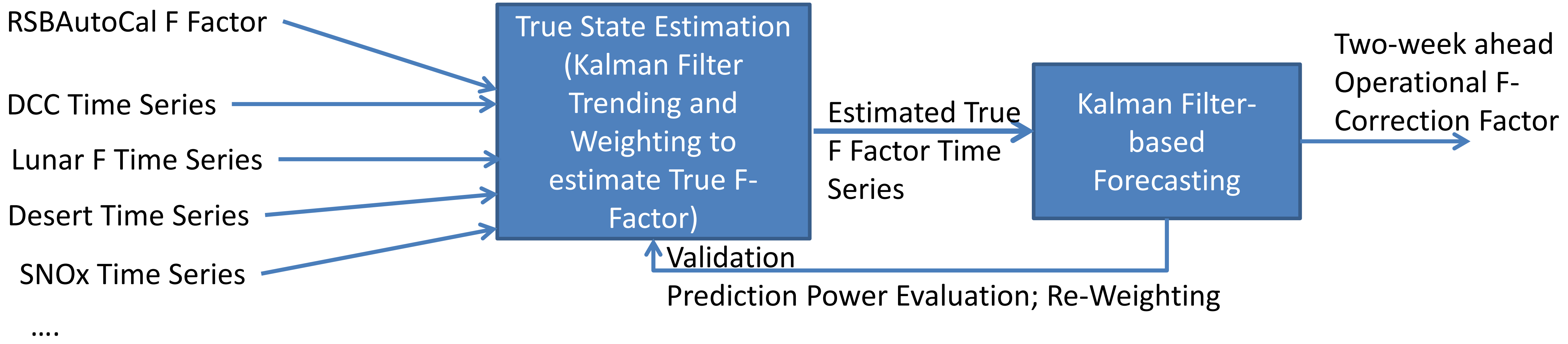
Contributors to this study: Changyong Cao, Bin Zhang, Jun Li, Zhenglong Li

VIIRS Solar Band Calibration Issue: Residual degradation in solar calibration

- M1 to M4 show underestimation of degradation in solar cal. (based on lunar cal. studies)
  - Both in IDPS and RSBAutoCal
  - DCC, desert monitoring, and SNOx with MODIS show trend in IDPS RSB SDR product
- Annual oscillation in solar-F factor
- ~2% bias of M5 and M7 radiance



Kalman Filter Model for F-Factor Correction Forecasting



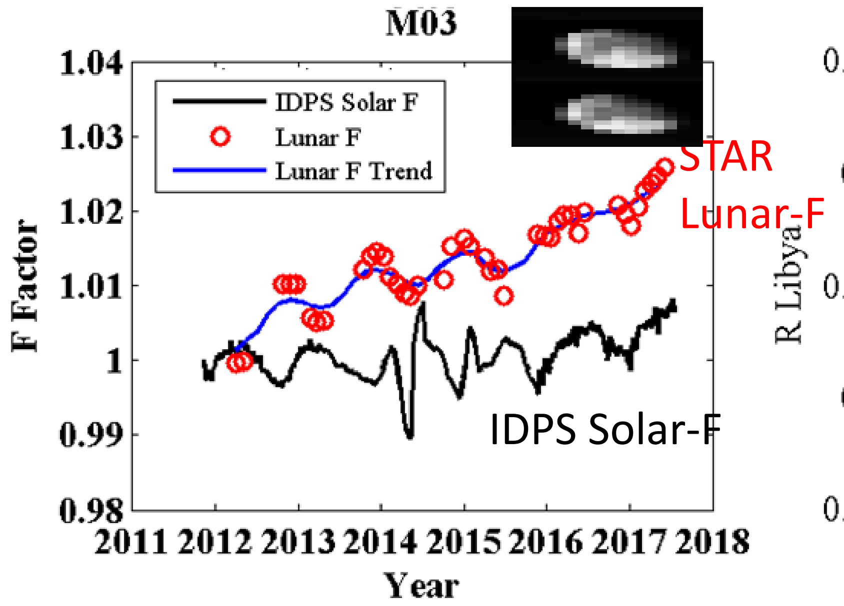
- Different time resolution (some at irregular interval)
- Different observations to characterize performance of the same detector (subject to measurement uncertainty and noise)
- Key steps
  - Kalman Filter trending
  - True State Estimation and Weighting Determination
  - Correction factor Prediction (Kalman filter prediction)

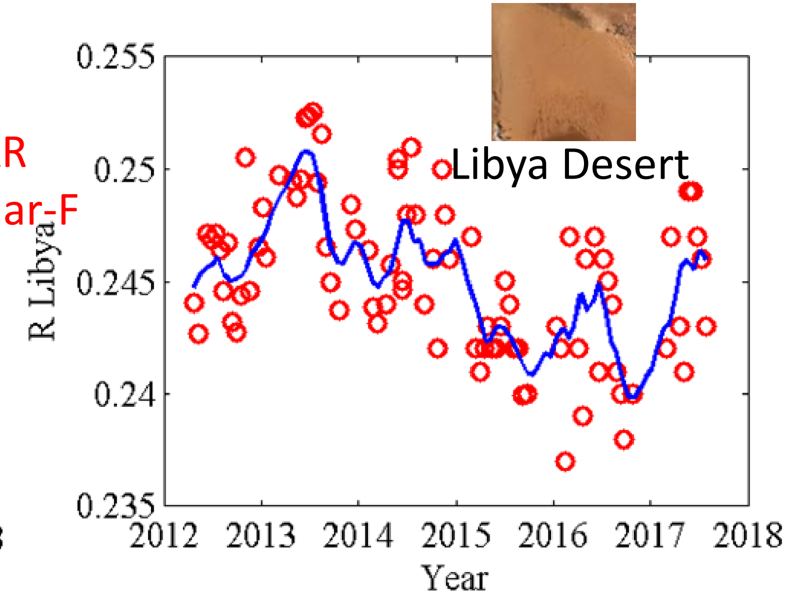
Data Sources

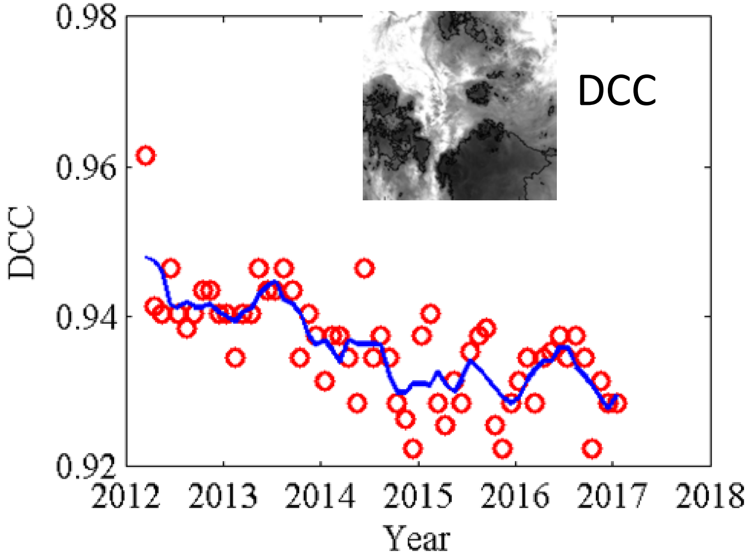
Monitoring Traget	Frequency	Interval	Note
IDPS Solar F	Daily	Launch to now	Derived from IDPS LUT
DCC Time Series	Monthly	Monthly (2012-01 to 2016-12)	Relative to IDPS data
Desert Time Series	Varies (~16 days)	2012 to 2017-04	Relative to IDPS data
SNO Time Series	Varies (~8 days)	2012 to 2017-04	Relative to IDPS data
Lunar-F	Monthly with 3-4 month gap each year	2012-04 to 2017-06	Derived from raw moon data normalized by GIRO model at NOAA/STAR
RSBAutoCal F	Orbit	Launch to now	

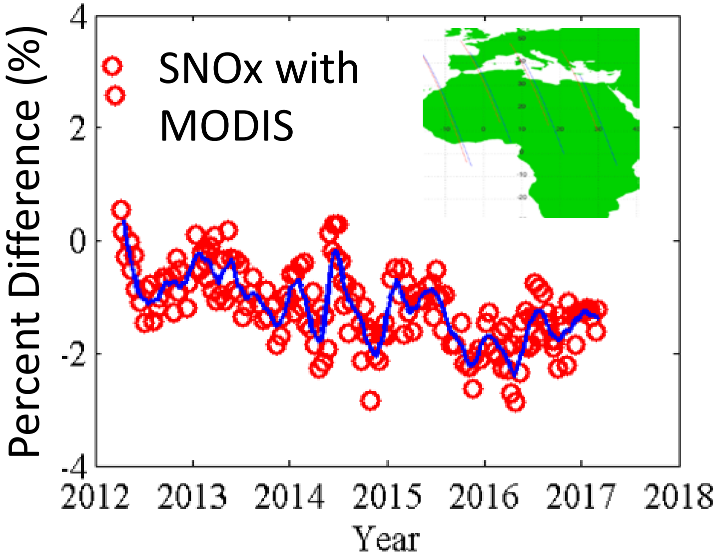
- In the following analysis, trend monitoring time series based on IDPS data are used.

Example of Trend Monitoring with Multiple Sources for VIIRS Band M3



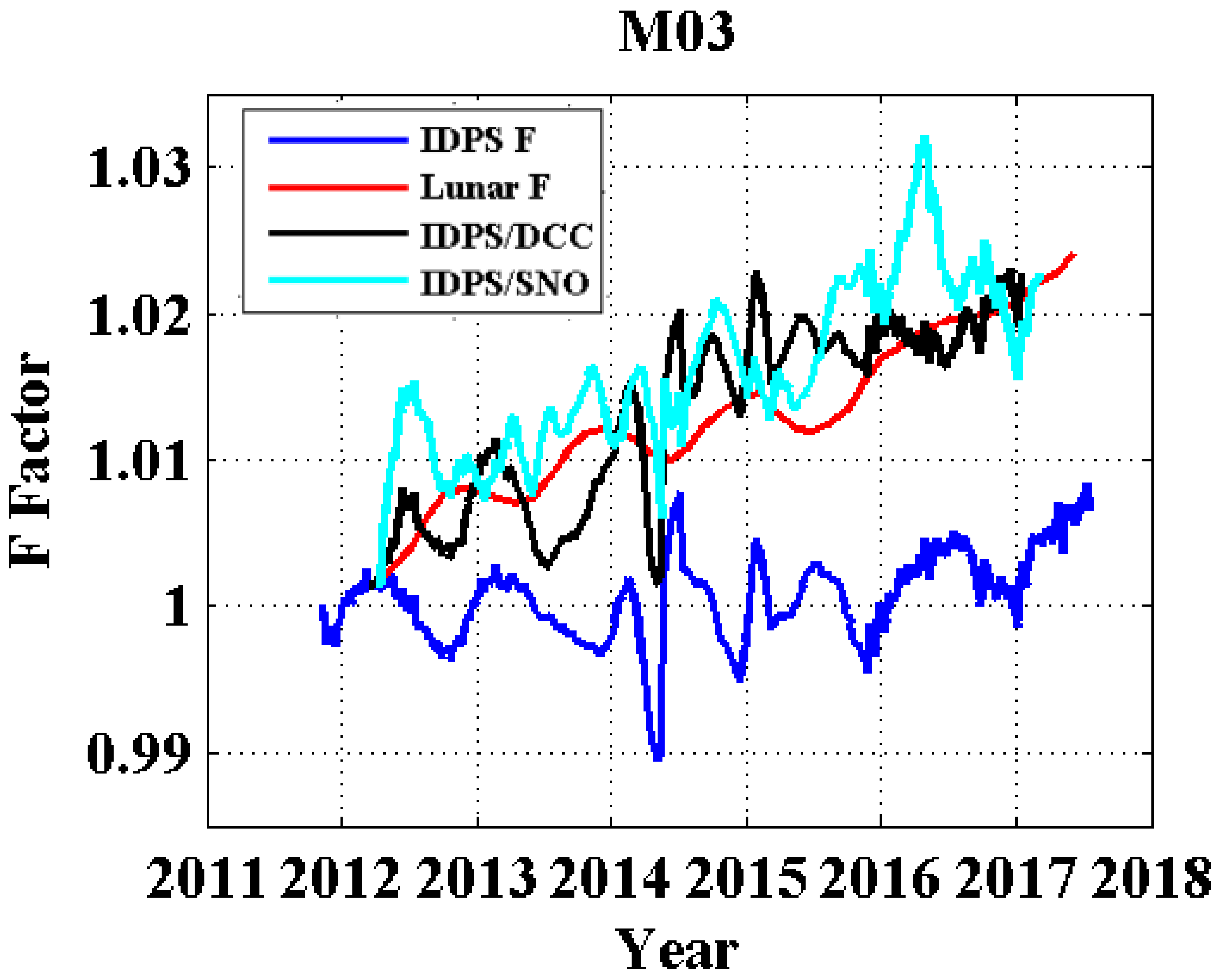






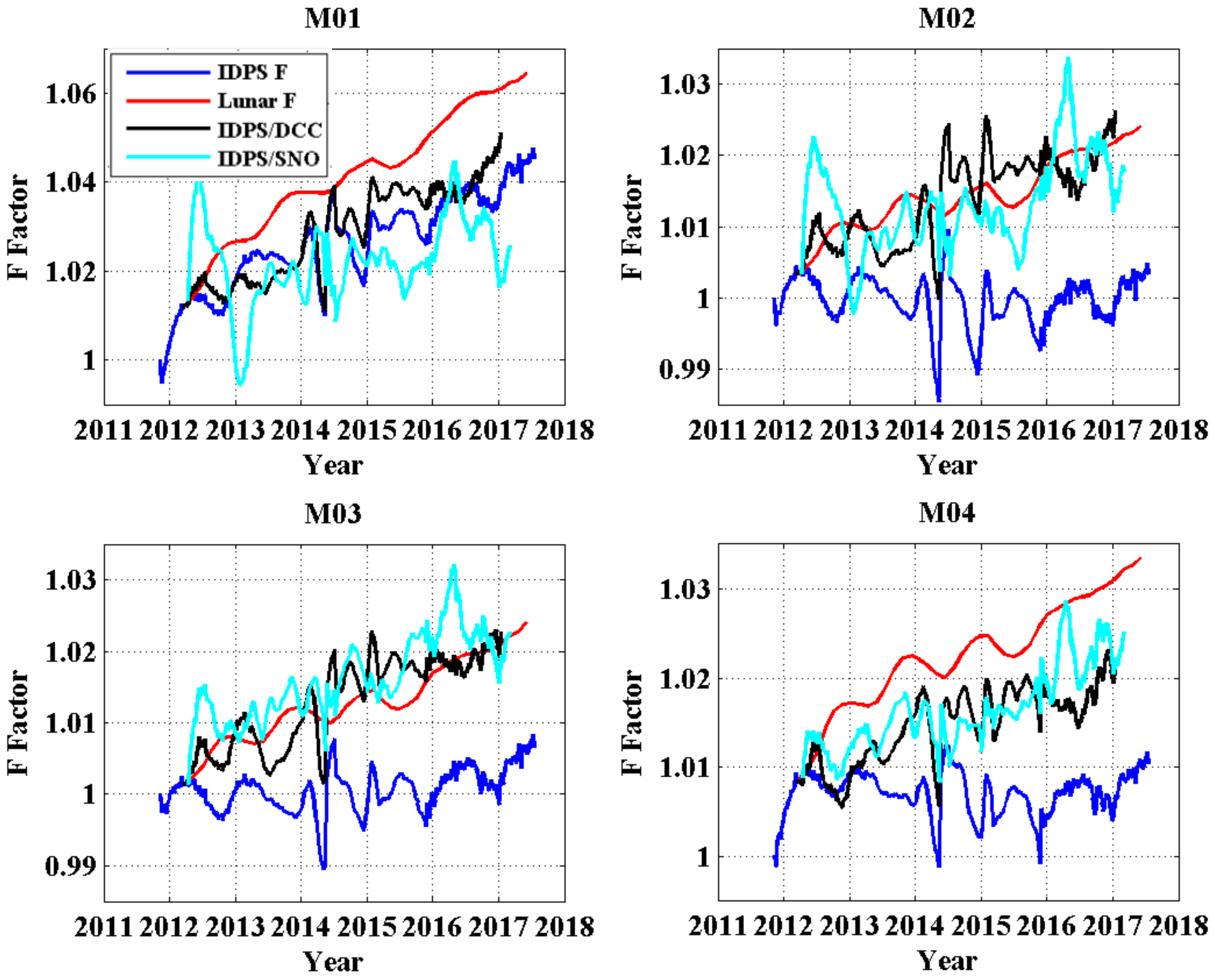
- Kalman Filter-based trend estimator
- NOAA/STAR Lunar-F clearly indicates underestimation of IDPS solar-F for M3 band.
- Consistent findings by NOAA-OC, NASA-VCST, NASA-OC, and NOAA-STAR
- DCC, Libya Desert and SNOx with MODIS
  - all are based on IDPS data
  - show similar downward trend
  - Point to same origin of underestimation by IDPS solar F factor
- Libya desert reflectance shows large oscillation due to BRDF. Need further processing.

Consistency Validation of Radiometric Trend Derived from Multiple Monitoring Sources (VIIRS M3)



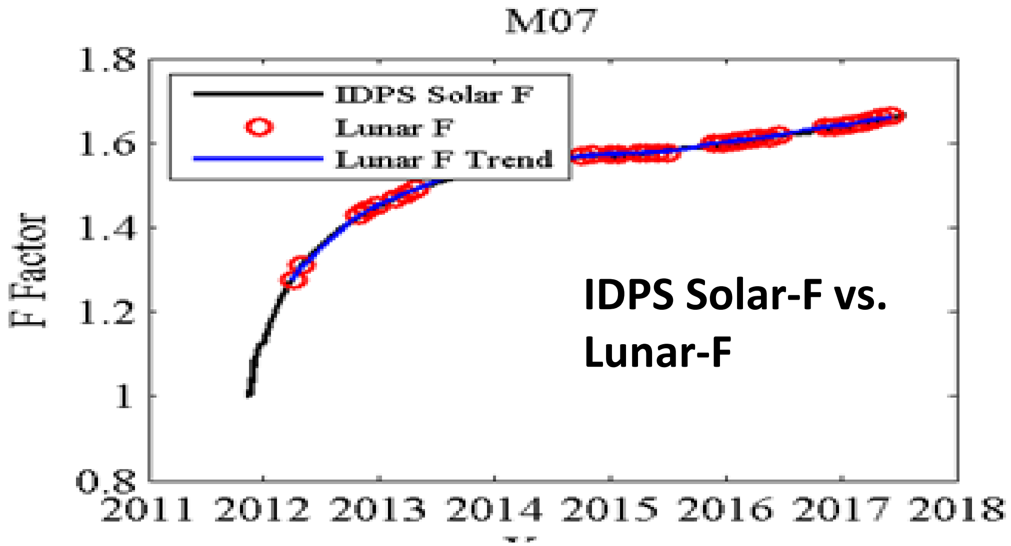
- IDPS Solar Diffuser F
- STAR Lunar-F
- DCC-Corrected F = IDPS F/(Normalized DCC Mode)
- SNO-Corrected F = IDPS F/(1+ SNO Difference%)
- VIIRS M3 Lunar observation, DCC and SNOx with MODIS all aligned with same trend;
- Consistent evidence of deviating from solar diffuser F factor.
- DCC and SNO data have larger fluctuation
- Possible Cause: Difference in RTA and SDSM view of SD BRDF

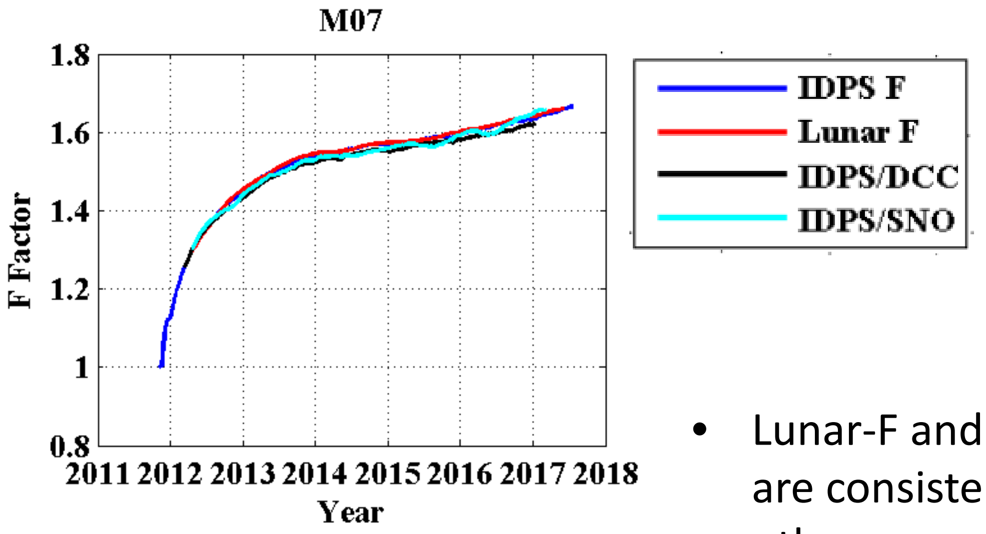
Consistency Validation of Radiometric Trend Derived from Multiple Monitoring Sources (VIIRS M1-M4)

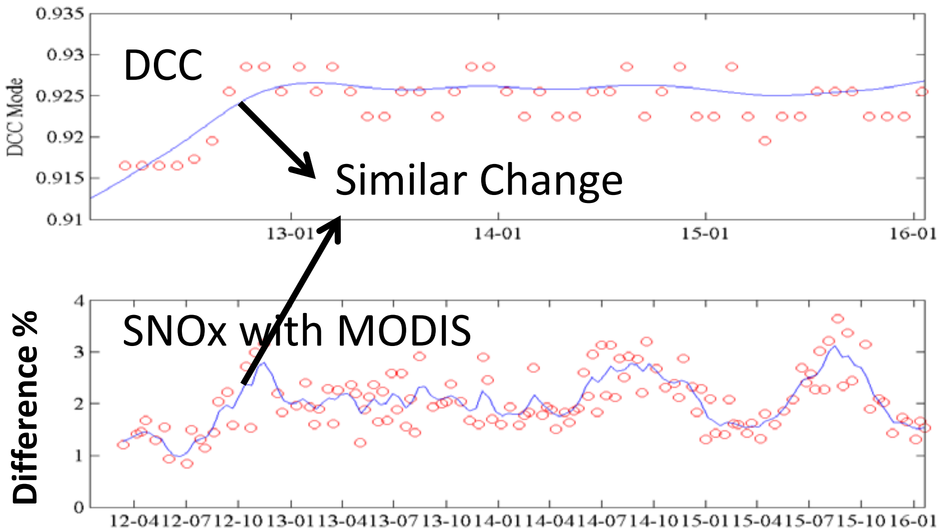


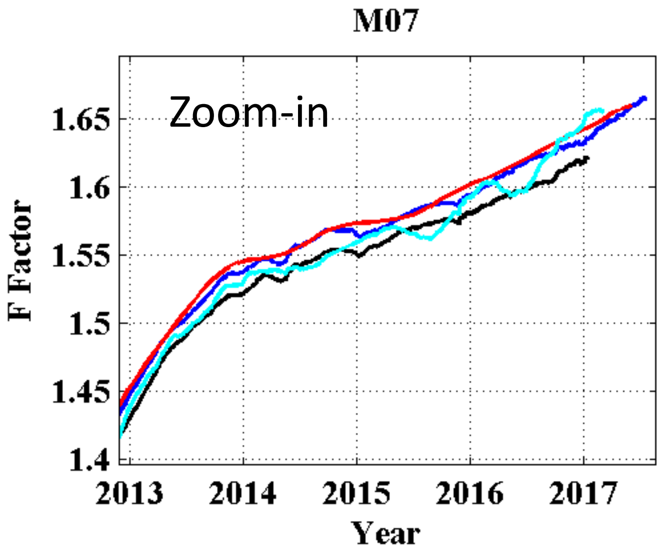
- IDPS Solar-F of M1-M4 all show underestimation of detector degradation
- VIIRS M2 and M3
  - Consistent trend among lunar-F, DCC-Corrected F and SNOx-Corrected F
- M1/M4: Lunar-F shows larger deviation.
- M4: DCC-Corrected F and SNOx-Corrected F are consistent
- M1/M2: SNOx-corrected F shows large fluctuation
- Strong evidence of consistency in trending from multiple sources

Radiometric Trend Monitoring for VIIRS M7







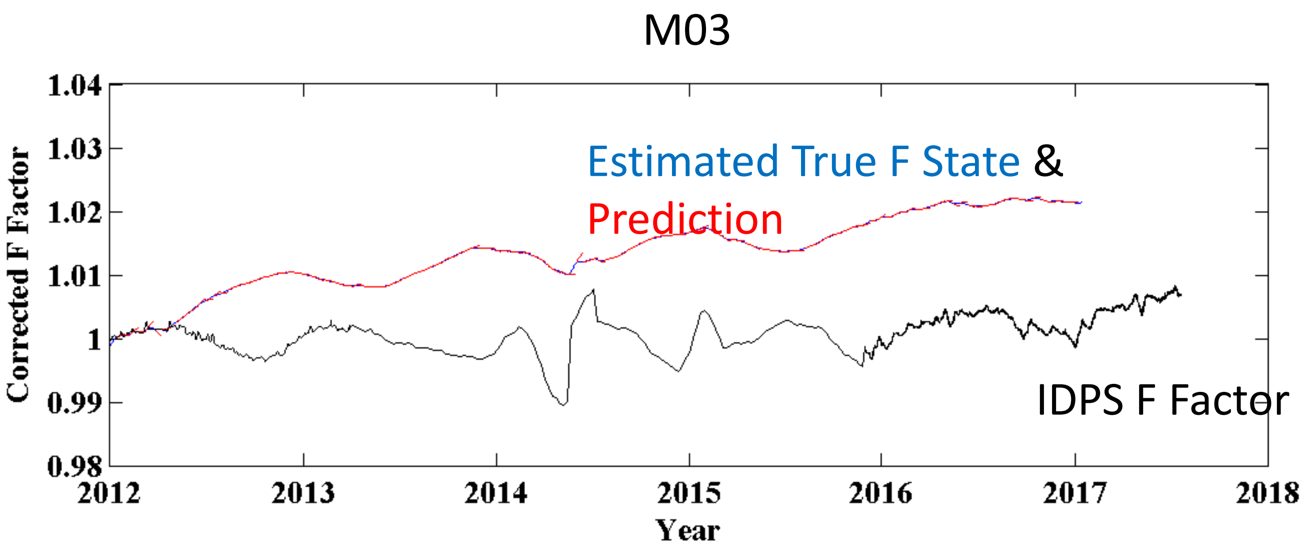


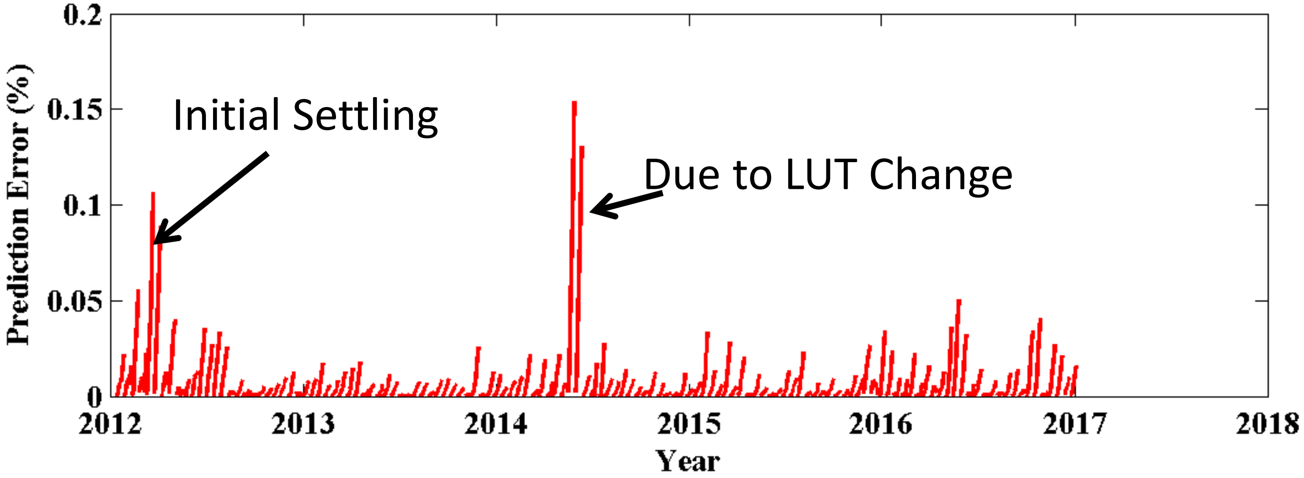
- Lunar-F and IDPS Solar-F are consistent with each other
- DCC and SNOx monitoring both show a change during middle of 2012.
- DCC-corrected and SNO-corrected F factor is lower in comparison to IDPS solar-F.

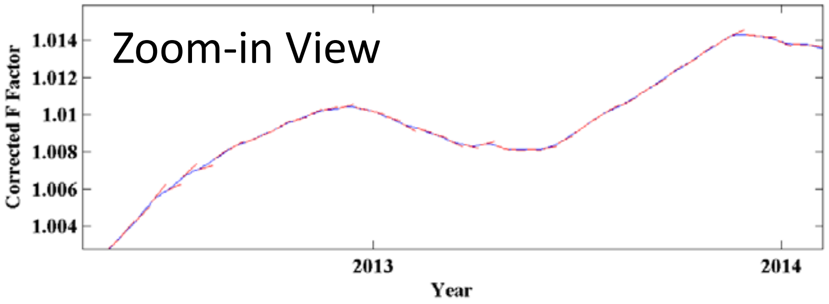
Development of Kalman Filter-based Predicative Model

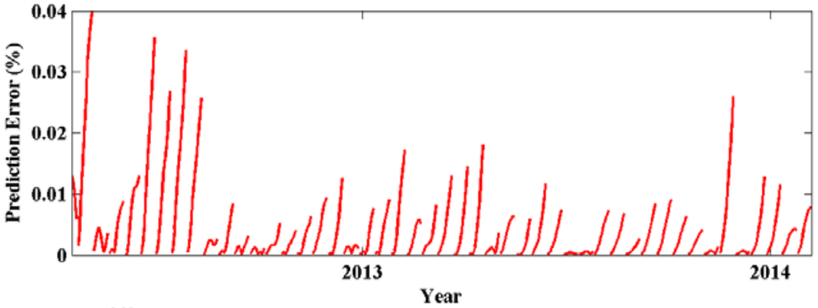
- In preparation for operational update of calibration scaling factor
- Need the bias correction two weeks in advance
  - Submission: two week ahead
  - Approval: One week
  - Operation: One week
- Combining inputs from multiple validation sources, estimate true-state F factor and perform 14-day prediction of scaling factor.
- Show preliminary results from the modeling efforts.
- Assessment of error or uncertainty sources.

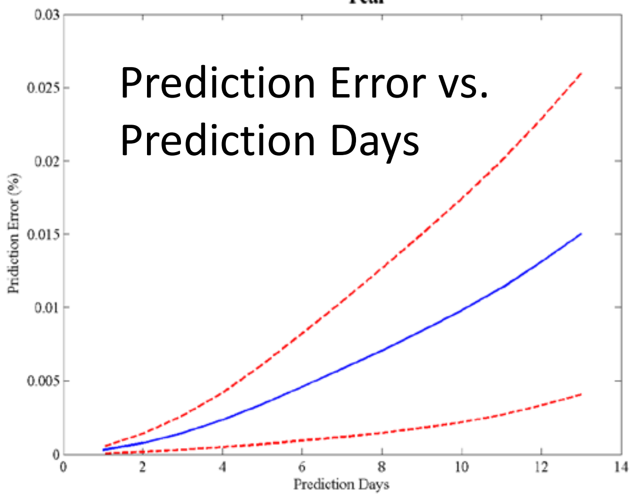
Kalman Filter-based Prediction Model (VIIRS M3)







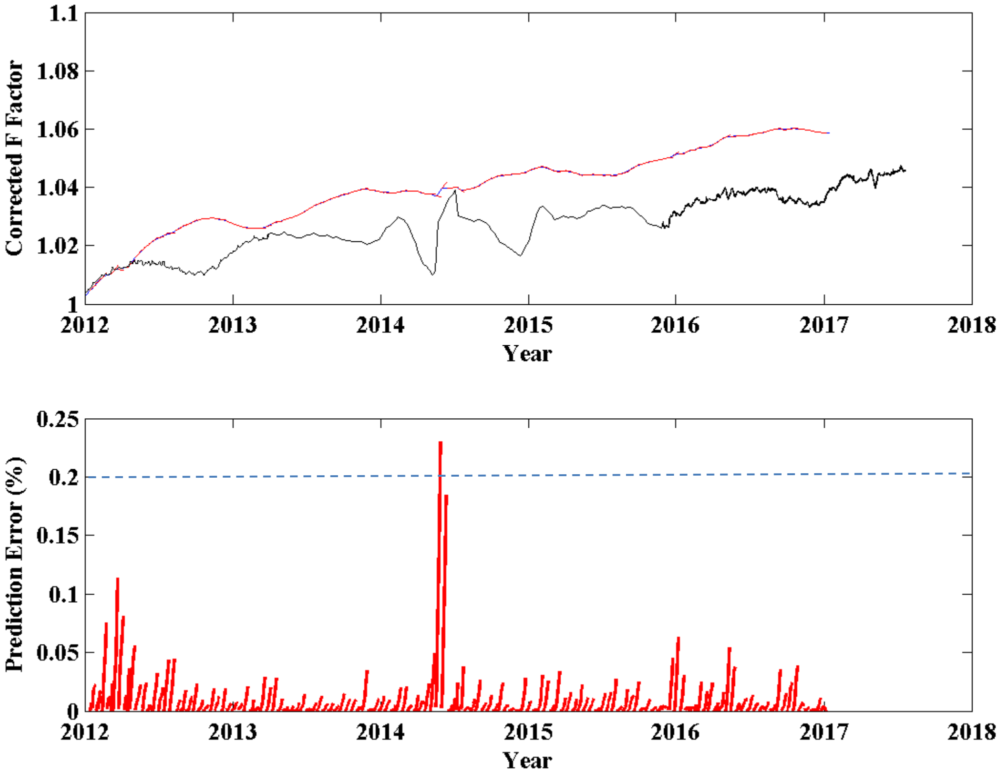




- Preliminary True F-Factor State estimation (80% Lunar, 10% DCC, 10% SNOx)
- 14-day forward daily prediction error within 0.2%

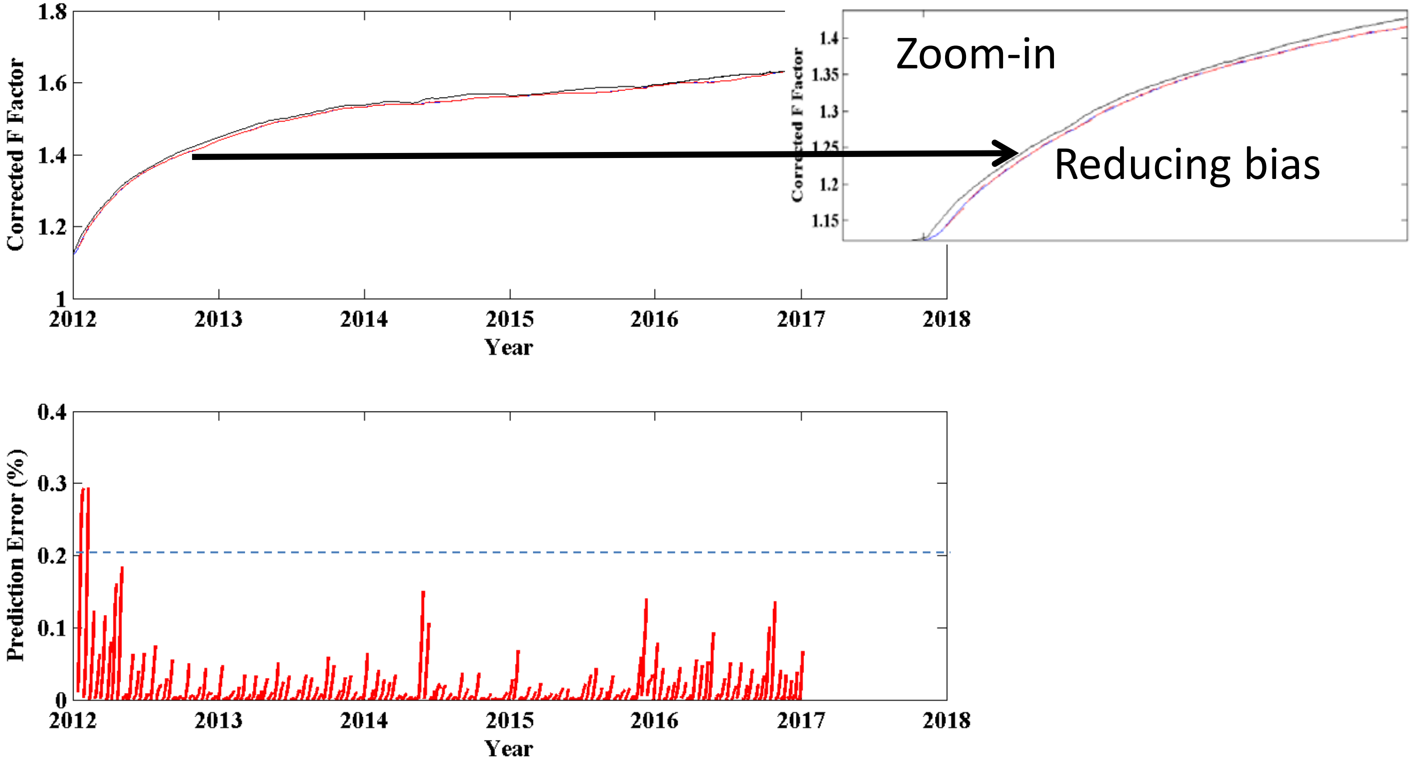
Kalman Filter-based Prediction Model (VIIRS M1-M4)

M1



- (80% Lunar, 10% DCC, 10% SNOx)

M7



- (1/3 Lunar, 1/3 DCC, 1/3 SNOx)

- Prediction model works for F factor with both gradual and rapid changes
- Large uncertainty at initial settling period and perturbation caused by manual updates
- Need further modeling on true F factor-state estimation for validation

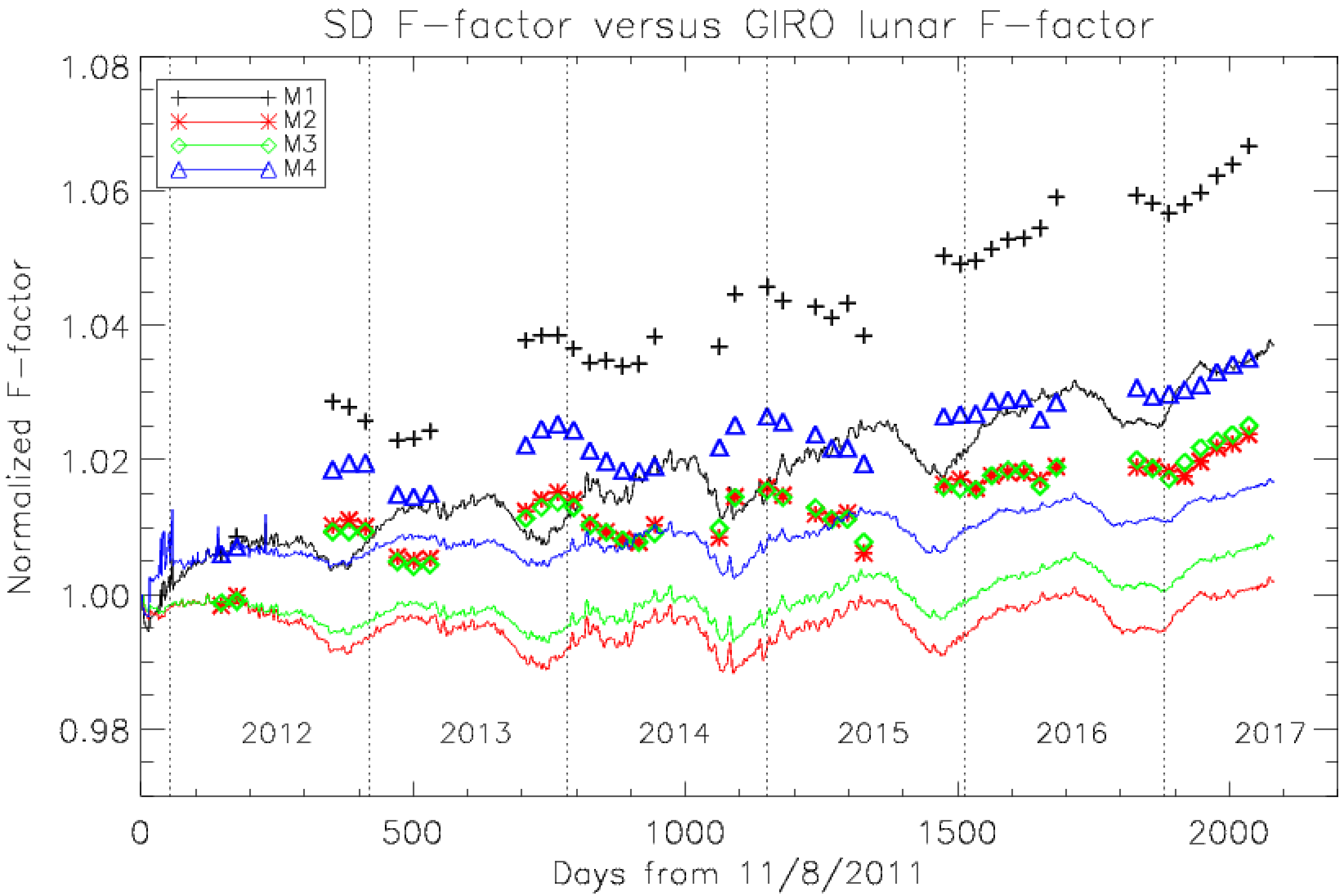
Summary and Path Forward

- Using IDPS solar F factor as an example, demonstrated consistency in VIIRS RSB calibration trend deviation from solar-F as monitored by Lunar-F, DCC, SNOx with MODIS and desert.
- On-going development of Kalman Filter-based predicative model to support near real time update of calibration coefficient.
- Path forward:
  - Uncertainty reduction in DCC , SNOx, ground target monitoring
  - Weekly DCC monitoring and fill the data gap with DCC-corrected F factor
  - Modeling and removal of annual oscillation in Solar-F and Lunar- F
  - True F Factor estimation and multi-source weight determination
  - Applications
    - Reprocessed VIIRS data with RSBAutoCal
    - Predictive Model to support near real time update of calibration coefficient for J1 VIIRS RSB

Contributors to this study:
Changyong Cao, Tom Liu, Wenhui Wang, Jason Choi, Sirish Uprety, Slawek Blonski, Bin Zhang

Back UP

VIIRS SDR Team Reprocessed Solar Cal.-F & Lunar-F



- IDPS Solar-F variations subject to LUT changes, and manual vs. auto updates etc.
- Reprocessed M1-M4 solar F factor still show deviation from lunar-F (Jason Choi's presentation on Tuesday (Aug. 15))
- To reconcile the difference in trending, DCC/desert/SNOx monitoring will be performed with reprocessed data.
- True F-factor state for reprocessed will be derived from multiple validation sources.
- Provided as a scaling factor for reprocessed data