Radiometric Stability and Consistency of VIIRS Global Area Coverage (VGAC) Reflective Solar Band Data over Calibration Sites

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Outline

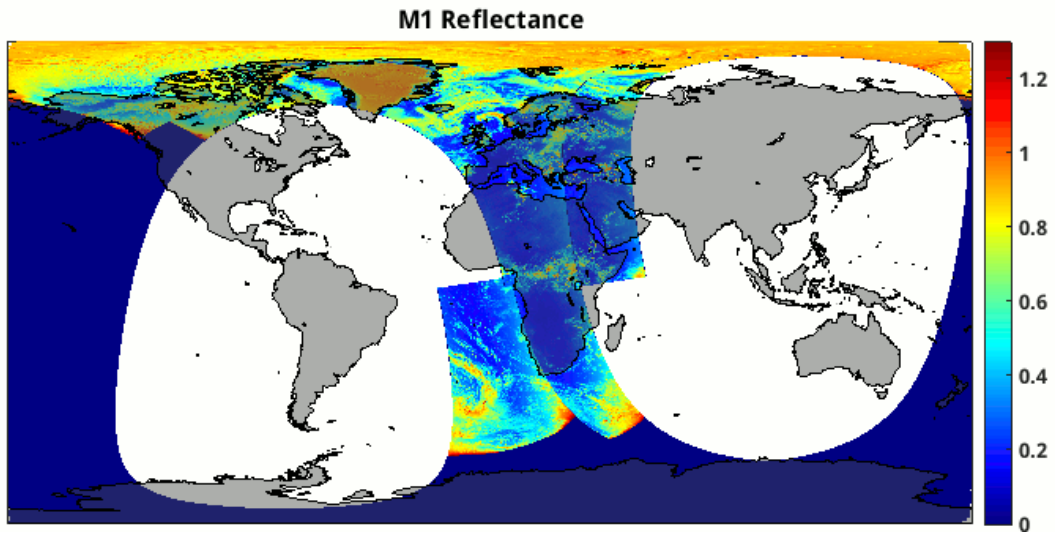
- Background
- Key features of VGAC
- Methodology
  - VIIRS recalibration and reprocessing
  - VGAC data sets used: from reprocessing and operational VIIRS SDRs
  - Pseudo Invariant Calibration Sites (PICS)
    - Desert sites, Dome C and Greenland
  - Reflectance time series over calibration sites
- Radiometric stability of S-NPP and NOAA-20 VGAC (from reprocessed VIIRS SDRs)
- Radiometric consistency of NOAA-20 and NOAA-21VGAC (from operational VIIRS SDRs)

Background

- VIIRS instruments onboard JPSS missions (S-NPP/NOAA-20/NOAA-21) produce Earth observations for over a decade. Crucial for weather forecasting, climate monitoring, disaster response, and tracking environmental changes.
- Challenges in distributing VIIRS Data in original format (VIIRS SDR data)
  - Resolution is too high for large-scale global processing for extending Climate Data Record.
  - Overlap among swaths. Varying spatial resolution with scan angle.
  - Large data volume
- VGAC was originated and designed by Dr. Ken Knapp of NOAA/NCEI
- VGAC product is derived from VIIRS sensor data record (SDR) at low spatial resolution, ensuring continuity of the decades of heritage products GAC from AVHRR, and enhancing accessibility and usability compared to standard VIIRS SDRs at full spatial resolution.
- Two types of VGAC data are being evaluated:
  1. From recalibrated and reprocessed VIIRS SDR data for improved accuracy and stability.
     - Suitable for developing long-term environmental data records (EDRs)
     - Analyze the long-term VGAC reflectance time series data from the recalibrated S-NPP (2012 to 2020) and NOAA-20 (2018 to 2022) RSBs to assess their stability and consistency.
  2. Processed from operational products for timely access to preliminary VGAC data
     - Evaluate the consistency of the preliminary NOAA-20 and NOAA-21 VGAC data over calibration sites.

VIIRS Global Area Coverage (VGAC) Data Generation

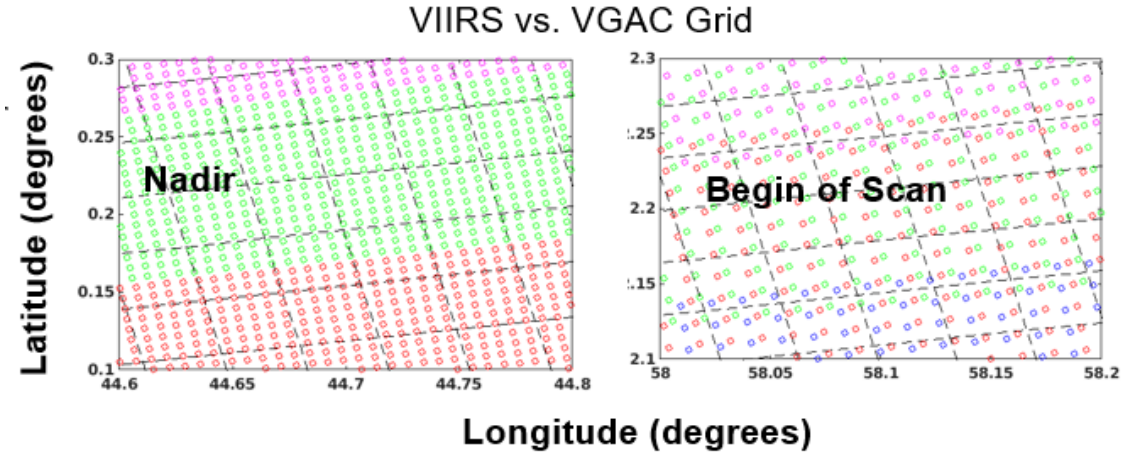
- VGAC is a reduced resolution reformat of VIIRS SDR data. It meets the requirements of climate data processing and is used as an input for several CDRs (Climate Data Records)
- NOAA/STAR produces VGAC data from recalibrated/reprocessed SNPP and NOAA-20 VIIRS SDRs, and operational NOAA-20/NOAA-21 VIIRS SDRs
- To provide to NOAA/NCEI for stewardship and distribution of VGAC (Primary POC: Ken Knapp) under the agreement https://www.ncei.noaa.gov/archive/atrac/export/2023-03-03T21-00-21.pdf?id=67709
- Being ingested to NOAA/CLASS and also available at anonymous ftp: ftp snpp.umd.edu



- Each VGAC Netcdf file contains one orbit of VIIRS SDR files
- ~470 MB each Netcdf file for one orbit
- ~6.5 GB for one day of 14-orbit VGAC data

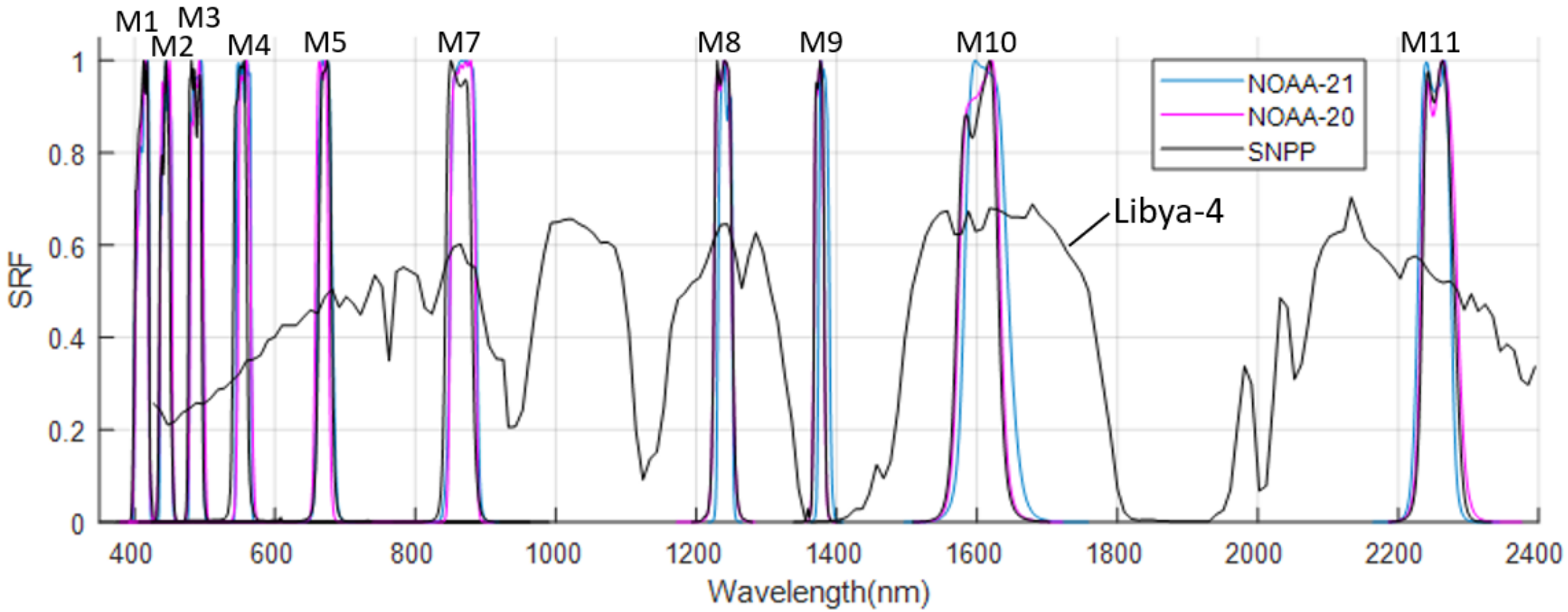
VGAC Data Format and Key Features

- Moderate resolution radiometric bands (M bands)
  - M1 – M11 reflectance mean and standard deviation
  - M12 – M16 infrared radiance mean and standard deviation.
  - M12 – M16 LUT, the radiance-to-brightness temperature mapping
- Imagery bands (I bands).
  - I1 – I3 reflectance mean and standard deviation
  - I4 – I5 infrared radiance mean and standard deviation
  - I4 - I5 LUT, the radiance-to-brightness temperature mapping
  - I1 – I5 max, min and sample reflectance/radiance
- Day-Night Band (DNB).
  - DNB radiance in (natural) logarithmic scale, mean value of all VIIRS pixels in the VGAC cell.
- Supporting variables
  - Geometry: orbit orientation, satellite/solar zenith and azimuthal angles.
  - Starting time of an orbit and the total time of an orbit.



- Improved VIIRS SDR accuracy and stability with recalibration and reprocessing
- VGAC divided the footprint of an orbit to an array of uniform cells (3.9 km × 3.9 km).
- ~50 times reduction in data volume at low spatial resolution for enhanced accessibility and portability
- Stored by orbit with roughly 14 orbit files per day.
- All channels and geolocation parameters are stored in one orbital netCDF file
- Facilitate long term EDR product (e.g., aerosol, cloud, polar wind) development
- Continuation of AVHRR GAC to support climate study

S-NPP/NOAA-20/NOAA-21 VIIRS RSRs



Correction Factors due to RSR Differences

	Target	M1	M2	M3	M4	M5	M7	M8	M10
NOAA-20 vs. S-NPP	Dome-C (Snow)	0.30%	0.10%	0.10%	-0.80%	0.20%	-0.40%	0.0%	
NOAA-21 vs. NOAA-20	Dome-C (Snow)	0%	0%	0.10%	0.20%	0.20%	-0.10%	-0.30%	
NOAA-20 vs. S-NPP	Libyan Desert	-1.10%	0.00%	0.10%	3.20%	0.30%	1.00%	0.10%	0.20%
NOAA-21 vs. NOAA-20	Libyan Desert	-0.10%	-0.10%	-0.10%	-0.60%	0.60%	-0.20%	1.50%	0.80%

Pseudo-Invariant Calibration Sites (PICS)

Desert Sites

- Selected 7 sites: Libya-1, Libya-4, Mauritania-1, Mautania-2, Egypt-1, Algeria-3, Arabia-2
- High reflectance, minimum vegetation, stable atmospheric conditions, low humidity, long-term stability
- Libya-4 (28.55°, 23.39°) is a CEOS endorsed cal/val site.

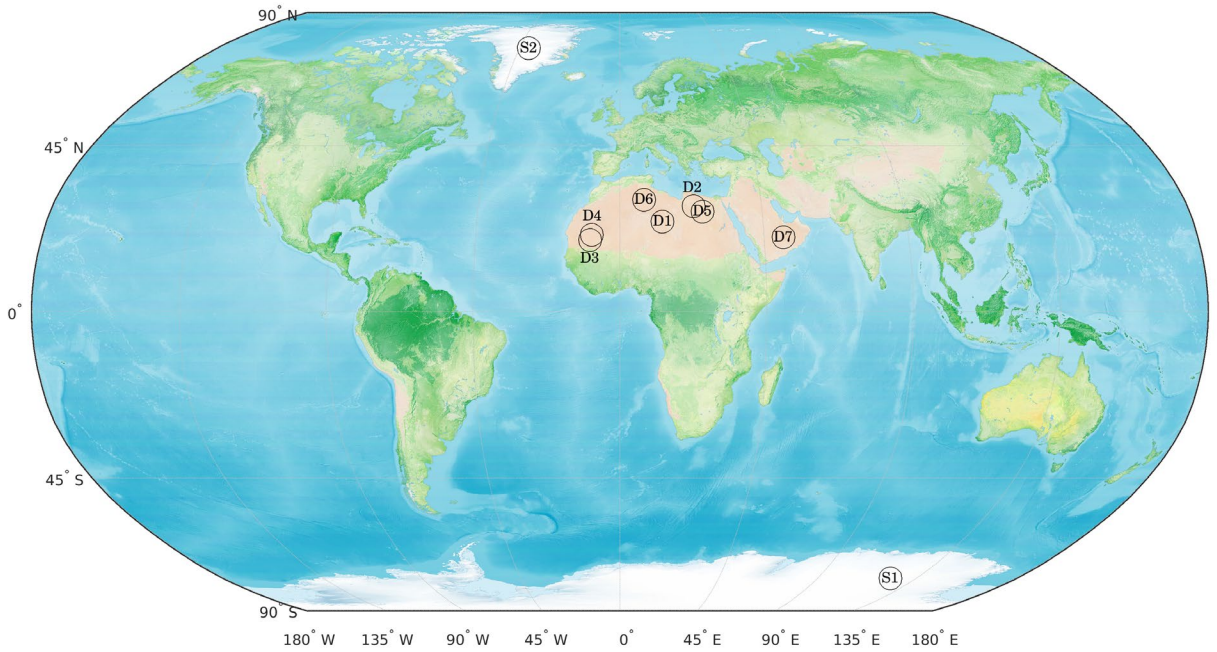
Dome C and Greenland (Snow Cover)

- Large homogenous snow field, high altitude, high reflectance; > 75% of cloud-free time; low water vapor content; very cold and dry climate; low aerosol and dust
- Limitations: accessibility, availability of data only during summer, high BRDF, not work well for SWIR band
- Dome C is endorsed by the CEOS.

Analysis Method

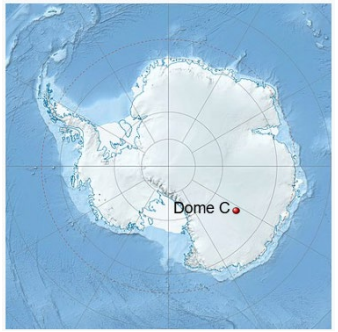
- Time series screening criteria: View Zenith Angle < 6°; Solar Zenith Angle < 75°; Uniformity (scene STD/Mean < 0.04) ;
- ROI: within 15 km radius
- Radiometric stability and consistency were characterized using TOA reflectance time series

D1: Libya1 (Desert site)
D2: Libya4 (Desert site)
D3: Mauritania1 (Desert site)
D4: Mauritania2 (Desert site)
D5: Egypt1 (Desert site)
D6: Algeria3 (Desert site)
D7: Arabia2 (Desert site)
S1: DomeC (Snow/Ice site)
S2: Greenland (Snow/Ice site)

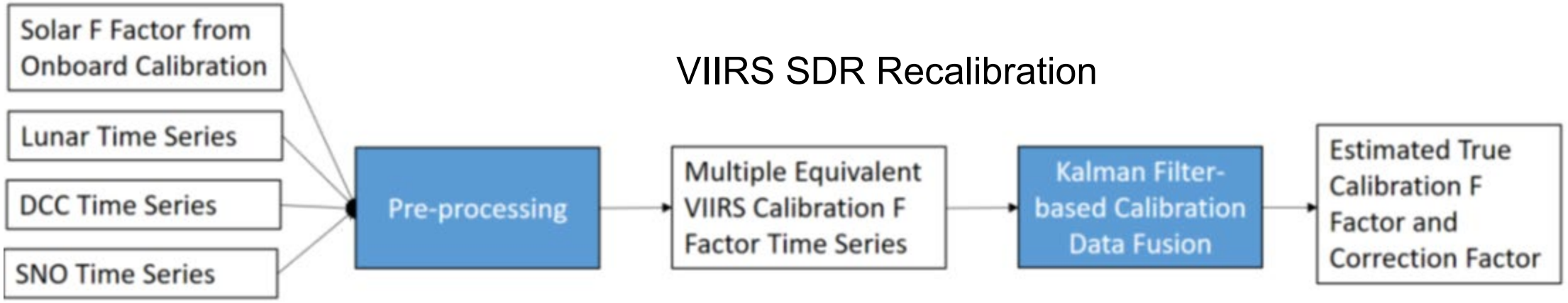


Desert

Dome-C



1. Stability assessment of SNPP and NOAA-20 VGAC data from recalibrated/reprocessed VIIRS SDR data

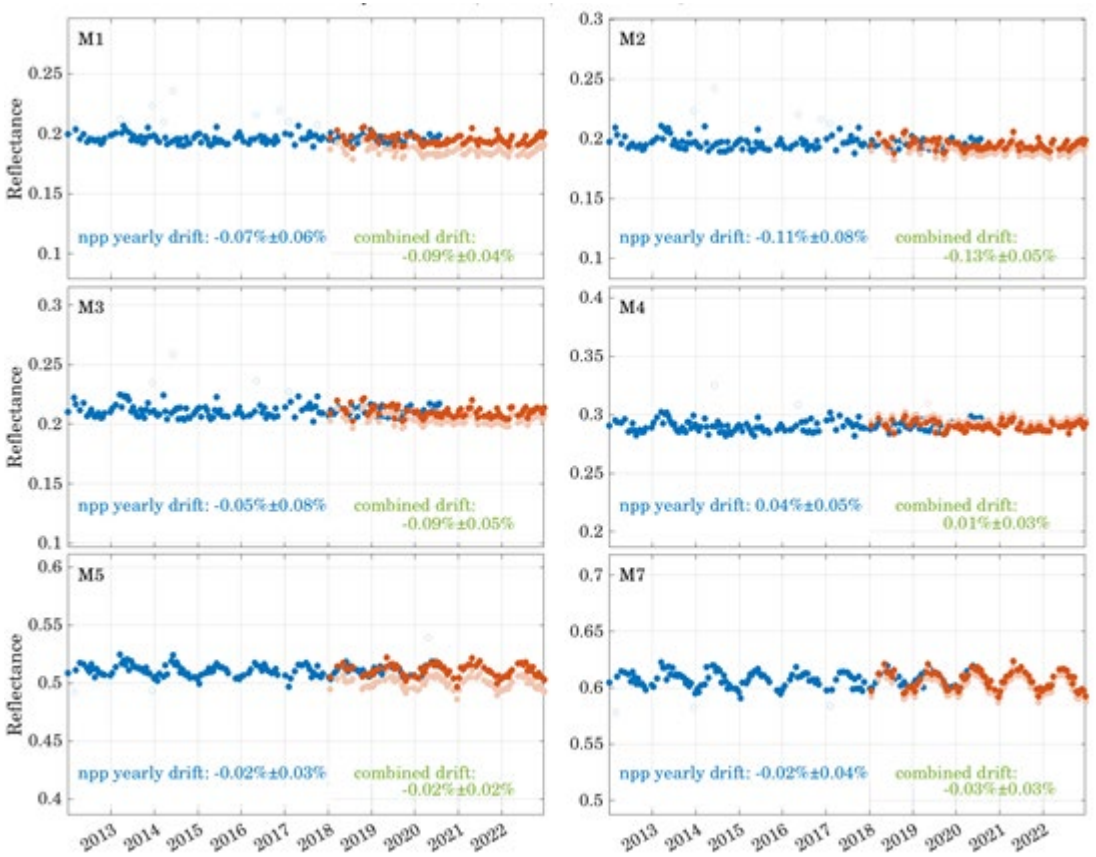


NOAA/STAR produces SNPP and NOAA-20 VGAC data from recalibrated/reprocessed VIIRS SDR data (Cao C., et al., *Remote Sensing*. 2021; 13(6):1075)

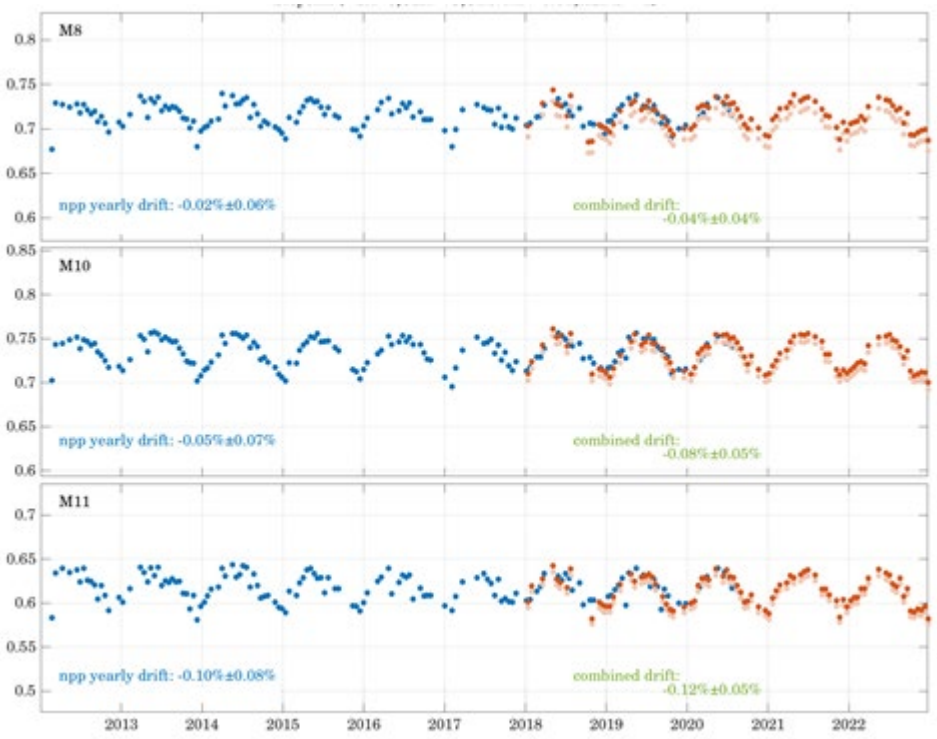
- **SNPP VIIRS (2012-2020)**
  - Using Thuillier (2002) solar spectrum (consistent with NOAA-20 and NOAA-21)
  - STAR Kalman Filter based bias correction factors based on Solar/LunarCal/DCC/SNO for VNIR bands; Constant bias correction M5/M7
  - STAR Surface Roughness-induced Rayleigh Scattering (SRRS) Solar Diffuser Degradation Model for SWIR bands
- **NOAA-20 VIIRS (2018-2022)**
  - Correction factors based on LunarCal and DCC trends for VNIR bands; SRRS Model for SWIR bands

Example S-NPP and NOAA-20 VGAC RSB Reflectance Time Series (from reprocessing) over Libya-1 Desert

VNIR Bands



SWIR Bands

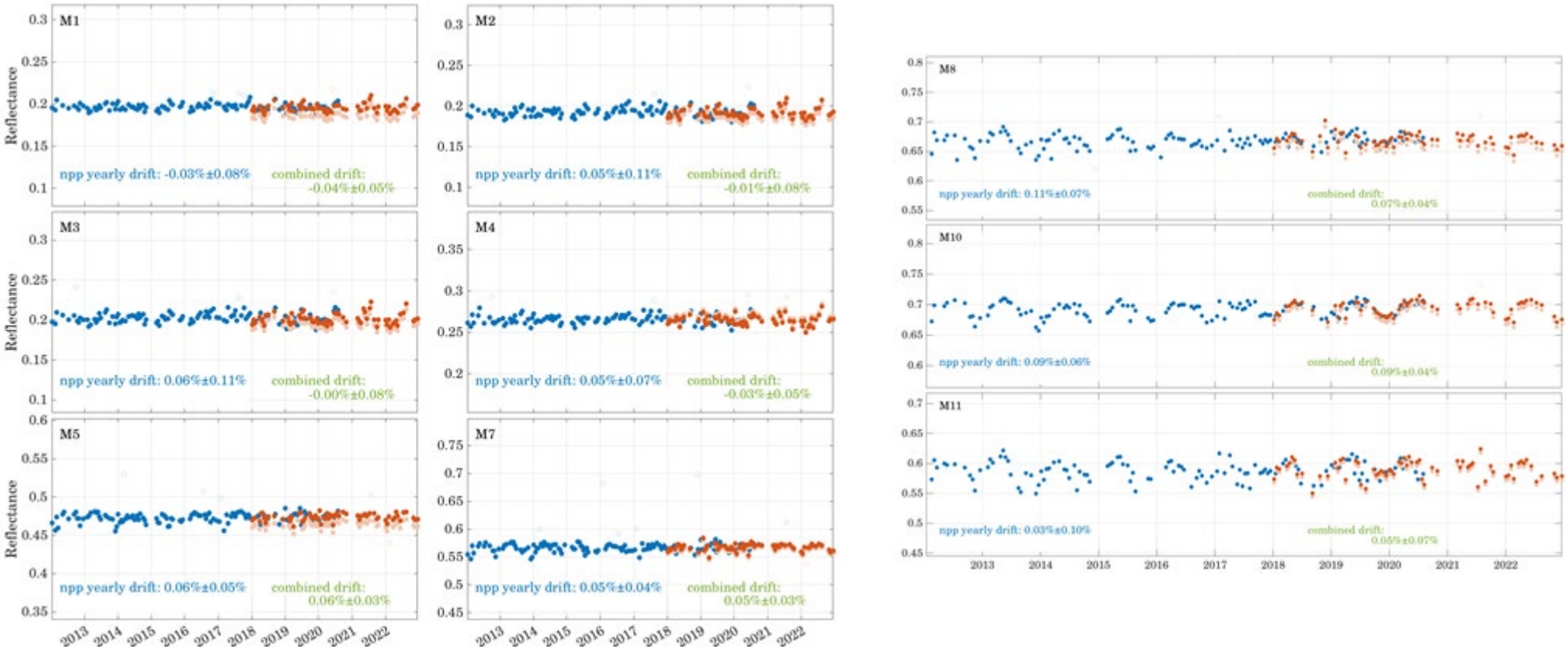


- Combined S-NPP and NOAA-20 reflectance time series: using overlapped periods to determine channel-dependent difference (%), and shift NOAA-20 time series to assemble combined time series for overall stability evaluation.
- Both S-NPP (~ 9 years) and combined (S-NPP+NOAA-20; 11 years) reflectance times series are stable (drift < 0.13%/year) over Libya-1 desert.

Example S-NPP and NOAA-20 VGAC RSB Reflectance Time Series (from reprocessing) over Mauritania-1 Desert

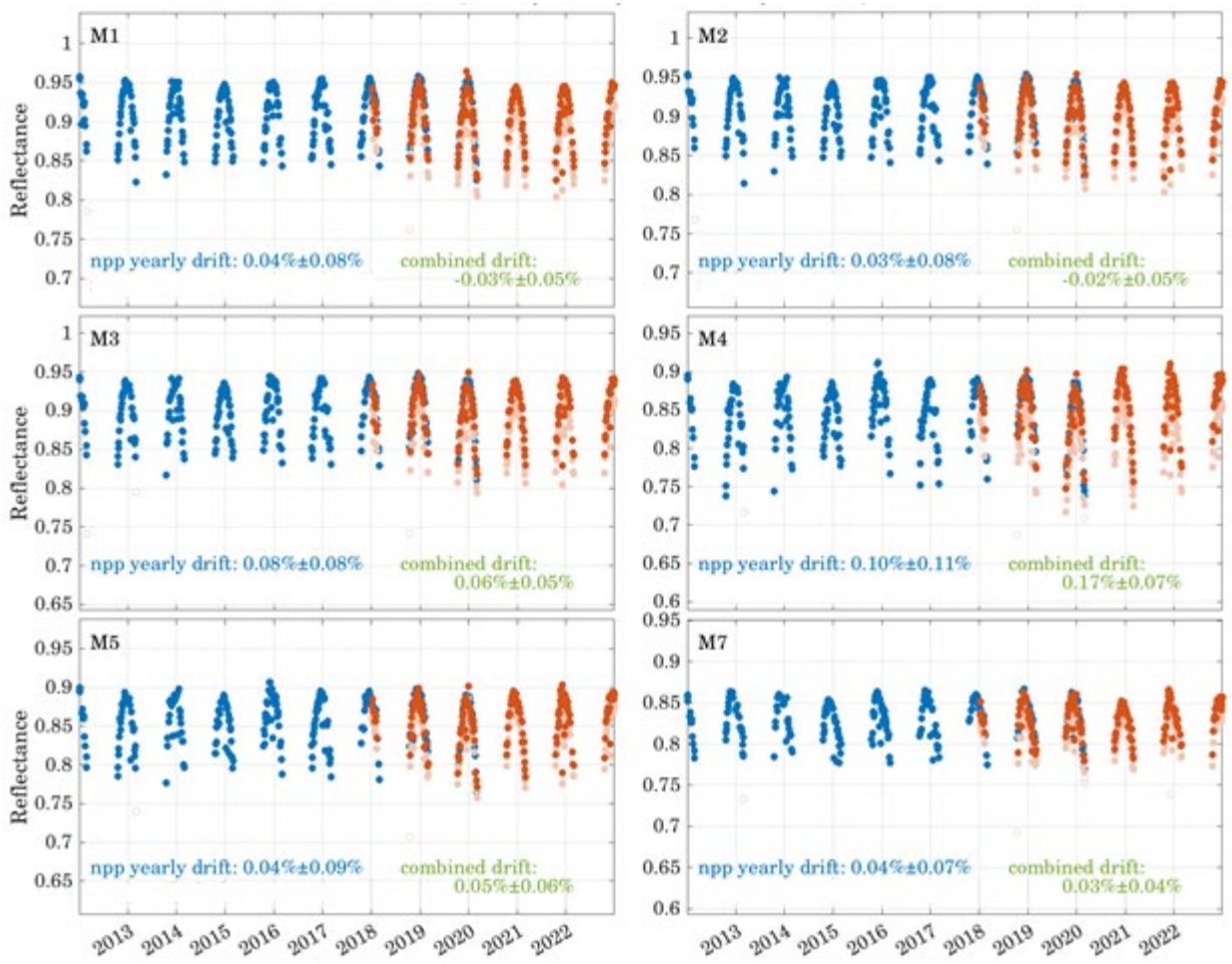
VNIR Bands

SWIR Bands



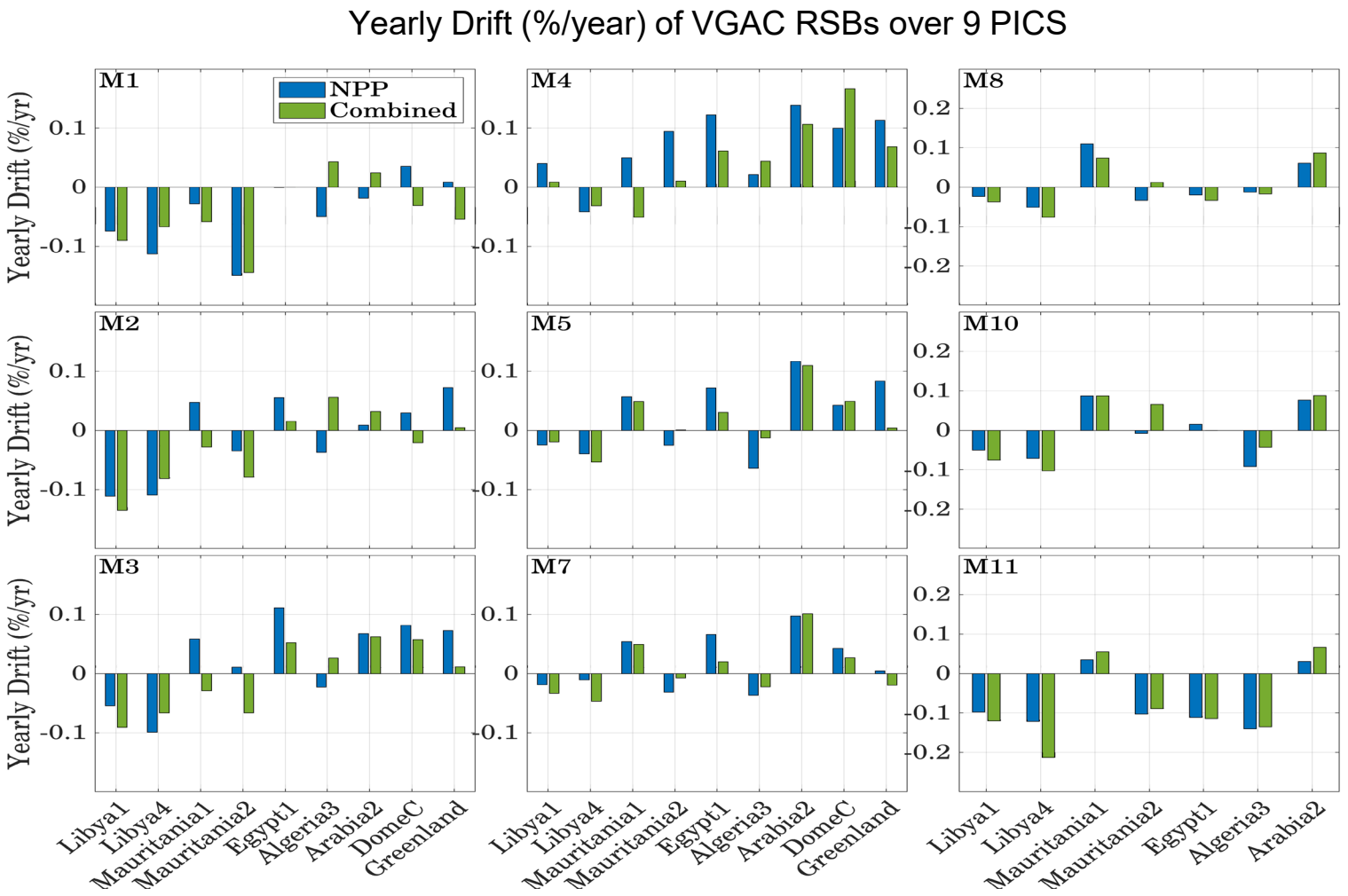
- Both S-NPP (~ 9 years) and Combined (S-NPP+NOAA-20; 11 years) reflectance times series are stable (drift < 0.1%/year) over Mauritania-1 site.

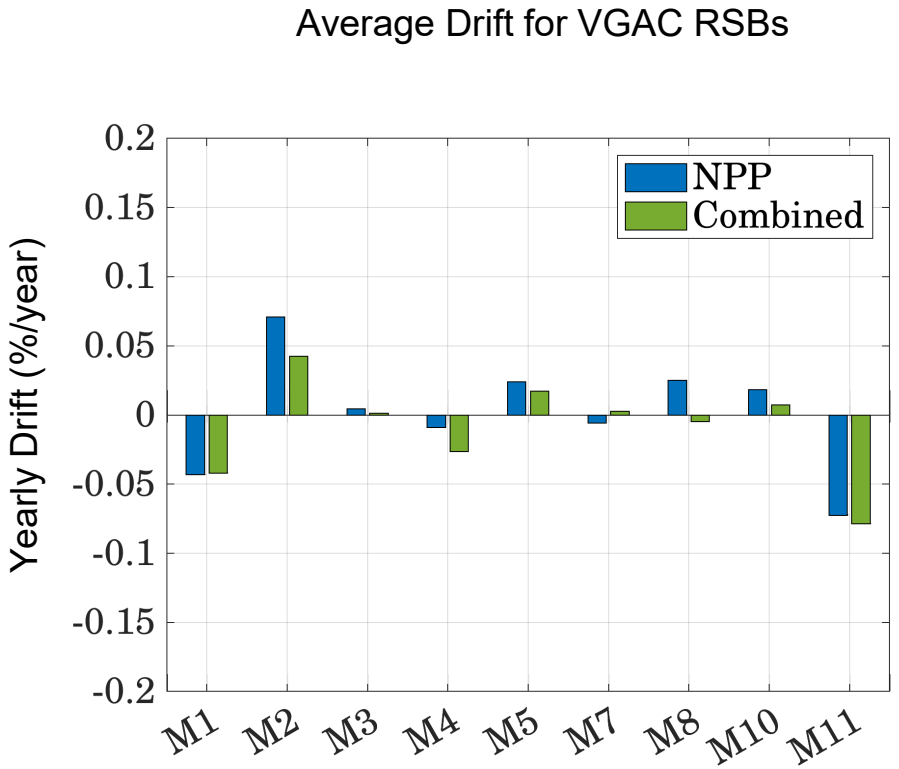
Example S-NPP and NOAA-20 VGAC RSB Reflectance Time Series (from reprocessing) over DOME-C Site for VNIR Channels



- Over Dome-C with high reflectance, both S-NPP and combined S-NPP+NOAA-20 reflectance times series are stable (drift < 0.1%/year) except M4.
- Greenland reflectance time series also shows consistent stability results

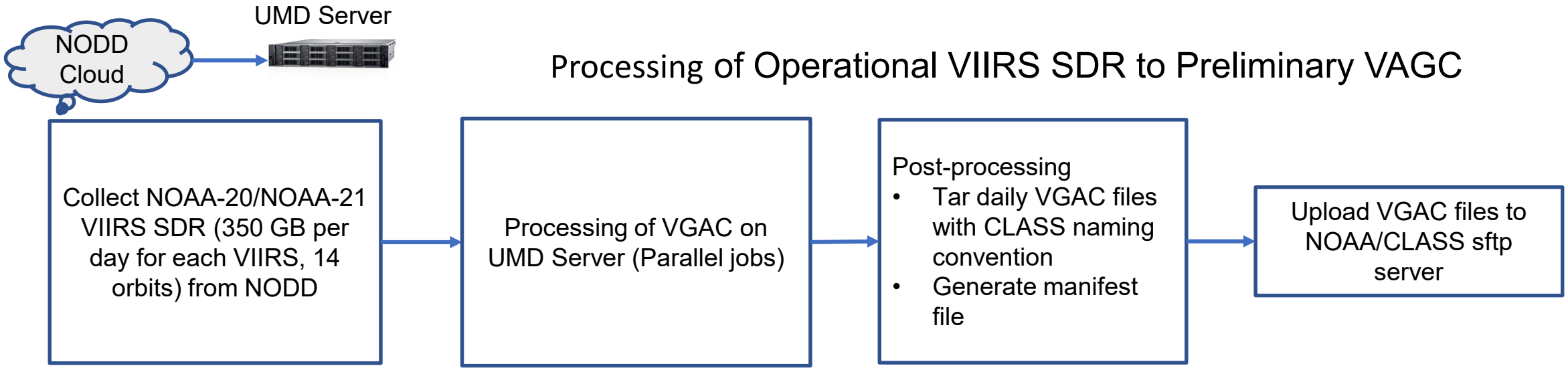
SNPP and Combined SNPP+NOAA-20 VGAC RSB (from reprocessing) Stability Over Seven Desert, Dome-C and Greenland Sites





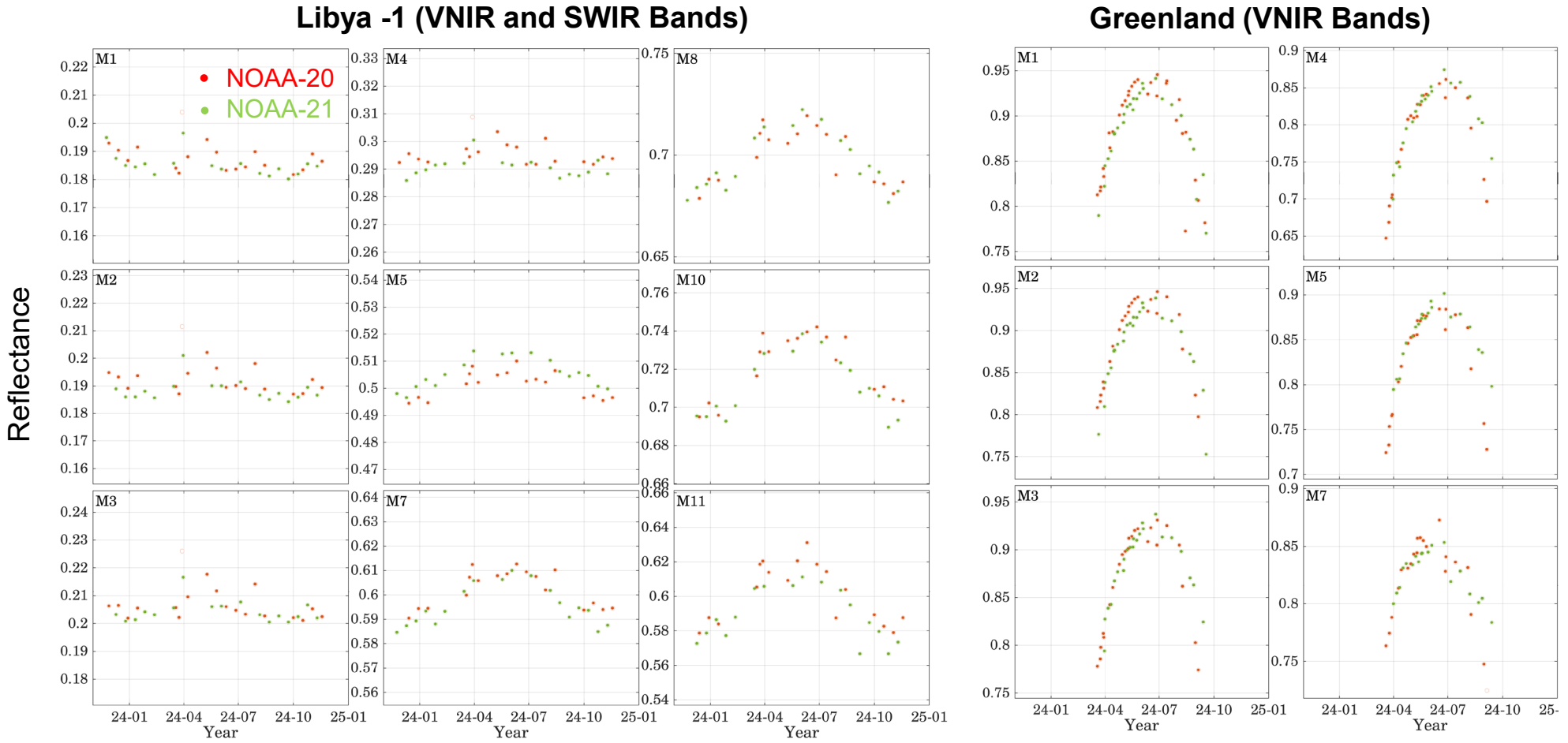
- SNPP+NOAA-20 VGAC data from recalibrated and reprocessed VIIRS SDRs suggest excellent temporal stability.
- **Average drifts from 9 sites for both SNPP and SNPP+NOAA-20 VGAC are better than 0.1% per year**

2. Consistency assessment of NOAA-20 and NOAA-21 VGAC data from Operational VIIRS SDR data



- NODD: NOAA Open Data Dissemination System (Cloud-based)
- Software modules were developed for automatized processing of VIIRS SDRs from NODD into preliminary VGAC for NOAA-20 and NOAA-21.
- Processing for NOAA-20 and NOAA-21 VGAC started in November 2023.

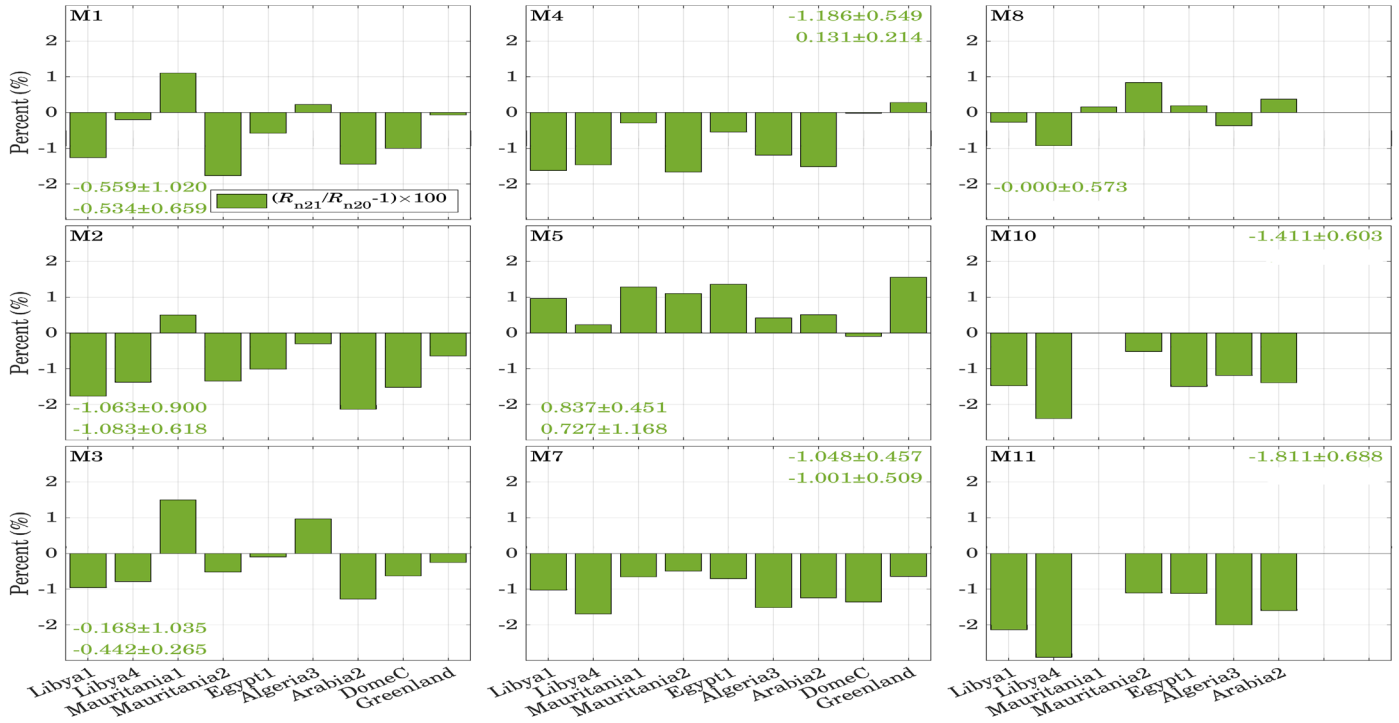
Example NOAA-20 and NOAA-21 (Preliminary) VGAC RSB Reflectance Time Series



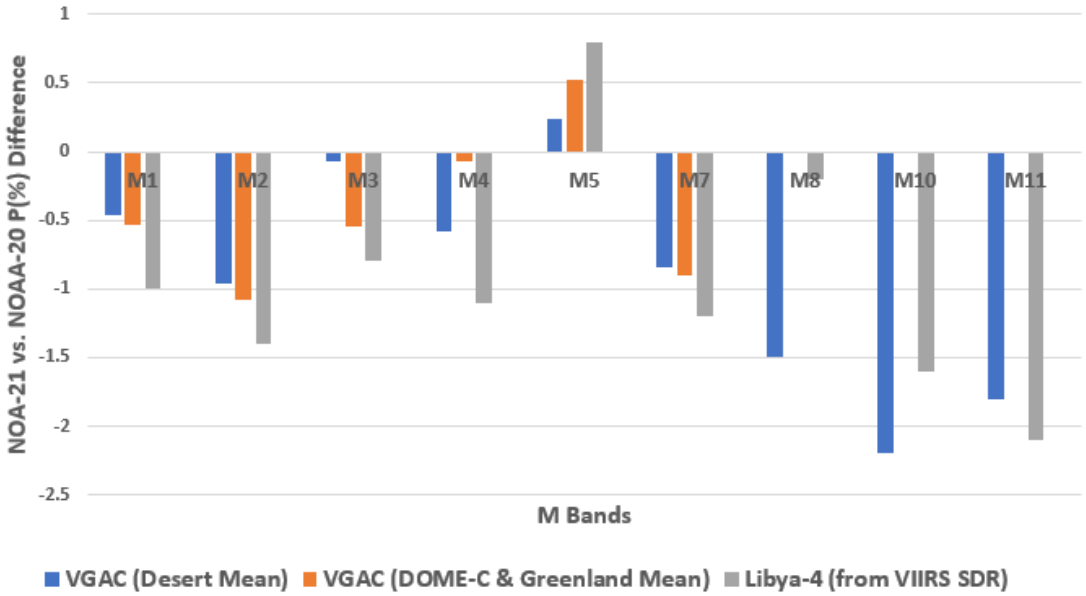
- Collected about 1-year NOAA-20 and NOAA-21 VGAC RSB reflectance time series over PICS
- Preliminary NOAA-21 vs. NOAA-20 comparison suggests consistency

Radiometric Differences of NOAA-21 vs. NOAA-20 VGAC over PICS

Percent Difference of NOAA-21 vs. NOAA-20 VGAC RSBs over 9 PICS
(Before SBAF Correction)



Comparison of NOAA-21 vs. NOAA-20 RSB Difference
(After SBAF Correction)



- Preliminary comparison of one-year NOAA-21 and NOAA-20 VGAC RSB reflectance data over deserts and Arctic/Antarctic sites indicated radiometric consistency to be within 2%
- Spectral radiometric differences are consistent between VIIRS SDR over Libya-4 and VGAC over deserts
- Longer period of overlapped NOAA-21 and NOAA-20 VGAC data can help reduce the uncertainty

Summary

- Assessed and validated the radiometric performance of the VGAC data processed from recalibrated SNPP and NOAA-20 VIIRS data and from operational NOAA-20 and NOAA-21 SDRs over seven desert sites, Dome C and Greenland.
- The VGAC RSB data from reprocessed SNPP (2012-2020) and NOAA-20 (2018-2022) are very stable.
  - Better than 0.1%/yr degradation for overall trends of SNPP (2012-2020) and combined SNPP+NOAA-20 (2012-2022) reflectance time series for all M bands.
- Preliminary comparison of NOAA-21 and NOAA-20 VGAC RSB reflectance over desert and Arctic/Antarctic sites indicated radiometric consistency to be within 2% for M1-M5 and M7-M11.
  - Longer period of overlapped VGAC data will help reduce the uncertainty of the assessment.
- The results presented in this study shows the excellent stability of decade-long VGAC using consistently recalibrated/reprocessed data and its suitability for wide range long-term scientific application studies that require stringent climate quality calibration.

References

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