

***Beta Maturity Science Review  
For Vegetation Health Products***



***Presented by Xiwu Zhan  
Date: 09/28/2023***

# JPSS/GOES-R Data Product Validation Maturity Stages - COMMON DEFINITIONS (Nominal Mission)

## 1. Beta

- Product is minimally validated, and may still contain significant identified and unidentified errors.
- Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
- Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

## 2. Provisional

- Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

## 3. Validated

- Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).
- Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
- Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
- Product is ready for operational use based on documented validation findings and user feedback.
- Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

# Maturity Review - Entry Criteria

- Product Requirements
- Pre-launch Performance Matrix/Waivers
- {Beta/Provisional/Validated} Maturity Performance Validation
  - On-orbit instrument performance assessment
    - Identify all of the instrument and product characteristics you have verified/validated as individual bullets
    - Identify pre-launch concerns/waivers, mitigation and evaluation attempts with on-orbit data
- Users/Downstream-Products feedback
- Risks, Actions, Mitigations
  - Potential issues, concerns
- Path forward (to the next maturity stage)
- Summary

# Maturity Review - Exit Criteria

- {Beta/Provisional/Validated} Maturity Performance is well characterized and meets/exceeds the requirements:
  - On-orbit instrument performance assessment
    - Provide summary for each identified instrument and product characteristic you have validated/verified as part of the entry criteria
    - Provide summary of pre-launch concerns/waivers mitigations/evaluation and address whether any of them are still a concern that raises any risk.
- Updated Maturity Review Slide Package addressing review committee's comments for:
  - Cal/Val Plan and Schedules
  - Product Requirements
  - {Beta/Provisional/Validated} Maturity Performance
  - Risks, Actions, Mitigations
  - Path forward (to the next maturity stage)



# BETA MATURITY REVIEW MATERIAL

- Algorithm Cal/Val Team Members
- Product Overview/Requirements
- Evaluation of algorithm performance to specification requirements
  - Algorithm version, processing environment
  - Evaluation of the effect of required algorithm inputs
  - Quality flag analysis/validation
  - Error Budget
- User Feedback
- Downstream Product Feedback
- Risks, Actions, and Mitigations
- Documentation (Science Maturity Check List)
- Conclusion
- Path Forward

## Algorithm Cal/Val Team Members

Name	Organization	Major Task
Ivan Csiszar	STAR	VIIRS Land Product Lead
Xiwu Zhan	STAR	VIIRS VHP Lead
Yan Luo	IMSG	Algorithm development, maintenance
Wei Guo	IMSG	Software, web

- Product Overview
  - Legacy satellite Vegetation Health Products have been generated for USDA and other users since 1990s. They are one of the primary inputs for global crop production estimate and forecast models, US Drought Monitor, Fire risk assessment, commodity future market researchers, etc
  - DPS-416: The Vegetation Health Index Suite shall provide vegetation condition index (VCI), temperature condition index (TCI), and vegetation health index (VHI); globally over land; geolocated; in daytime; in clear conditions.
  - DPS-418 The Vegetation Health Index Suite shall provide vegetation health indices with a horizontal cell size of 4 kilometers
  - DPS-419 The Vegetation Health Index Suite shall provide vegetation health indices with a refresh every 7 days

**Verification Method:** Demonstration



# Product Overview/Requirements (2 slides)

- DPS-416: The Vegetation Health Index Suite shall provide vegetation condition index (VCI), temperature condition index (TCI), and vegetation health index (VHI); globally over land; geolocated; in daytime; in clear conditions.
- Product performance requirements from JPSS Data Product Specification (DPS)

Attribute	DPS	Requirement/Threshold	Performance
Accuracy	DPS-422	1%	n/a
Precision	DPS-420	4%	Temporal consistency
Uncertainty	DPS-421	4km (3-sigma) for 4km product	Spatial consistency
	DPS-420, 421, 422	<b>Verification Description:</b> To be verified against truth data, selected at the discretion of the algorithm provider, demonstrating compliance over the range of production conditions. Index values range from 0 to 100%.	

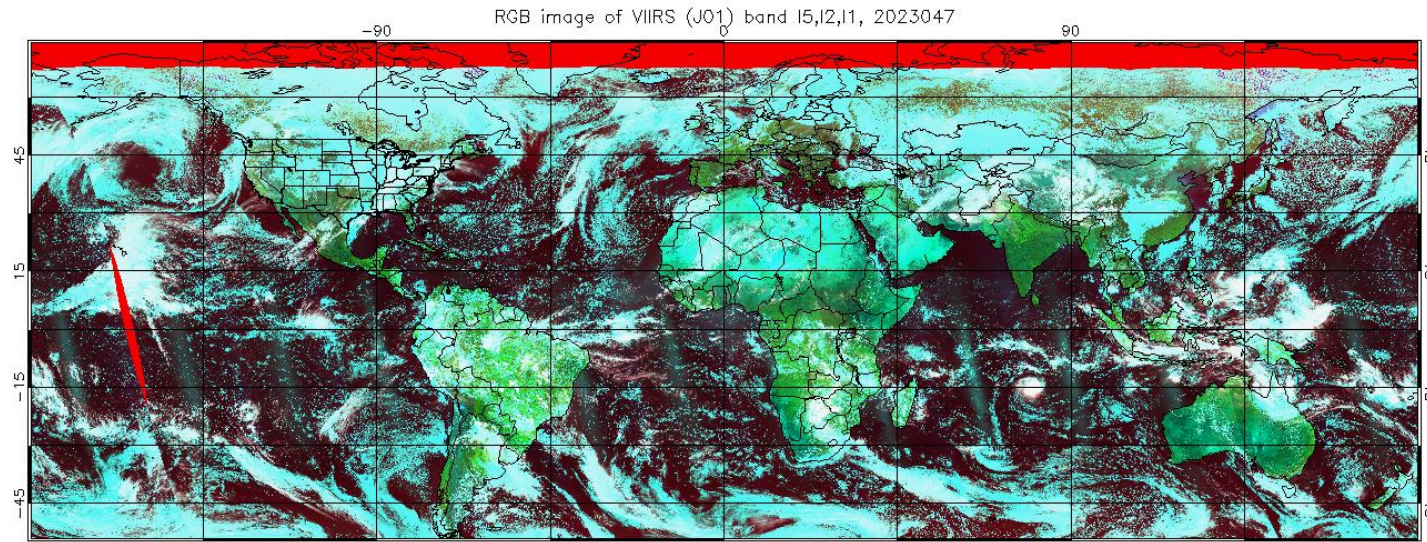
# Product Evaluation Strategies (2 slides)

- Evaluation Methods for VHP of N21 VIIRS:
  - Vegetation Health Indices/Products (VCI, TCI & VHI) do not have exact the same ground measurements, thus no validation of these variables could be carried out;
  - VHP from AVHRR, S-NPP and N20 observations have been intensively evaluated by product team and world wide users in the past decades via demonstrating their correlations with crop yields, drought occurrence, vector disease epidemic, wildfire occurrence, etc.
  - For VHP of N21 VIIRS, the evaluation is carried out against VHP from N20 VIIRS before longer time series of N21 VHP becomes available;
  - The following slides demonstrate the global N20 and N21 differences of VIIRS radiances RGB maps, surface reflectance of specific bands, smoothed NDVI (SMN), smoothed thermal channel brightness temperature (SMT), vegetation condition index (VCI), temperature condition index (TCI), and the final vegetation health index (VHI);
  - Differences of available time series of these variables for representative locations between N20 and N21 VIIRS observations are also demonstrated.

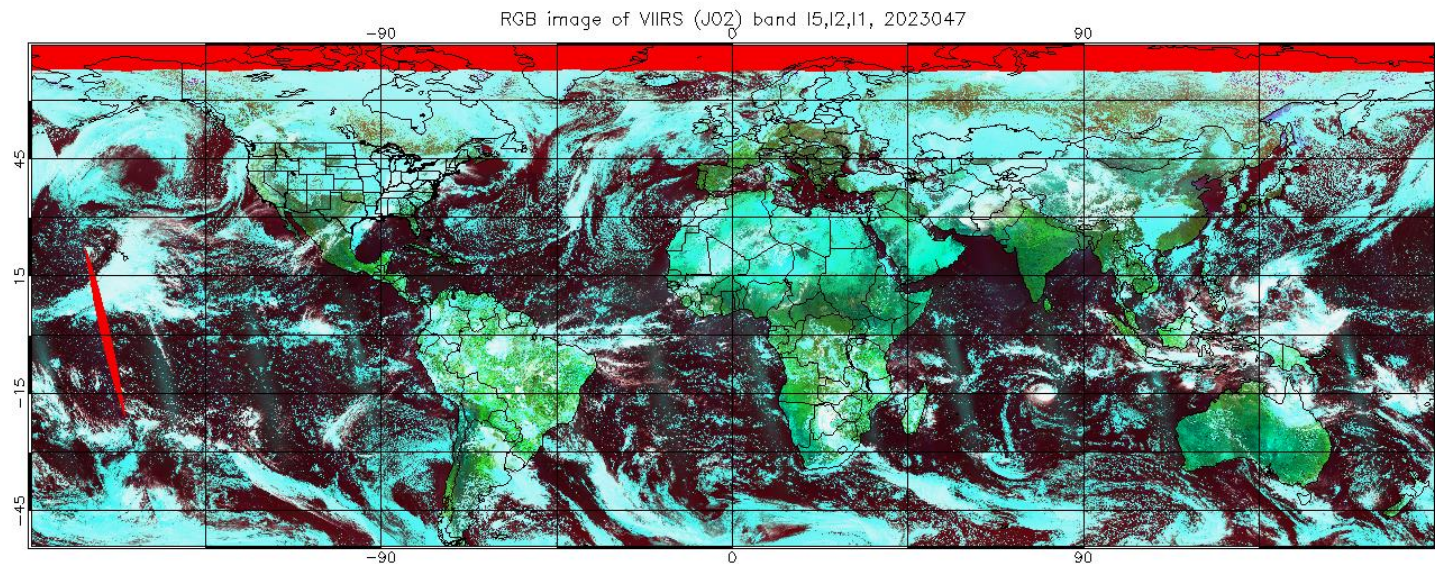
## Verification Method: Demonstration & Difference Statistics

# Daily RGB map (2023047) of J01 and J02

J01 / N20



J02 / N21

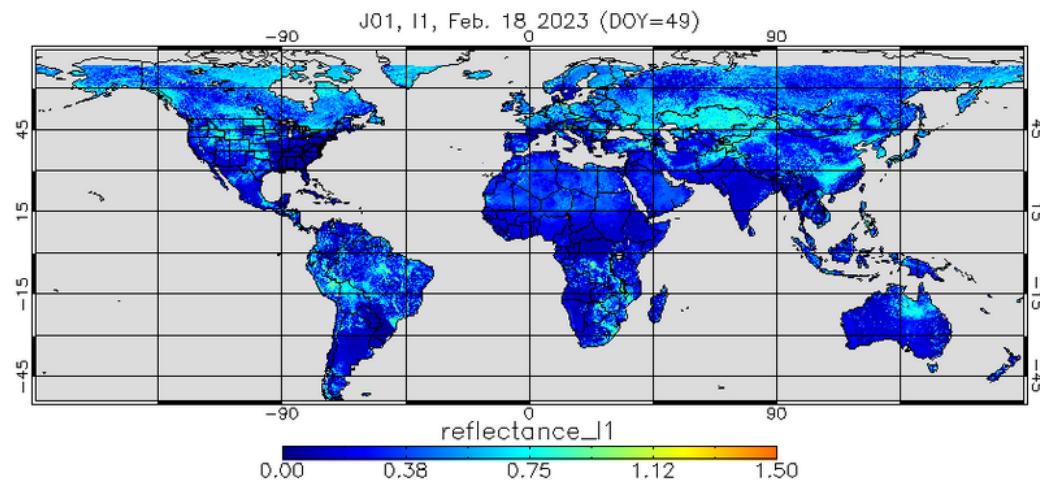


# Compare reflectance: J01 vs J02

## Band I1, 2023 day 49

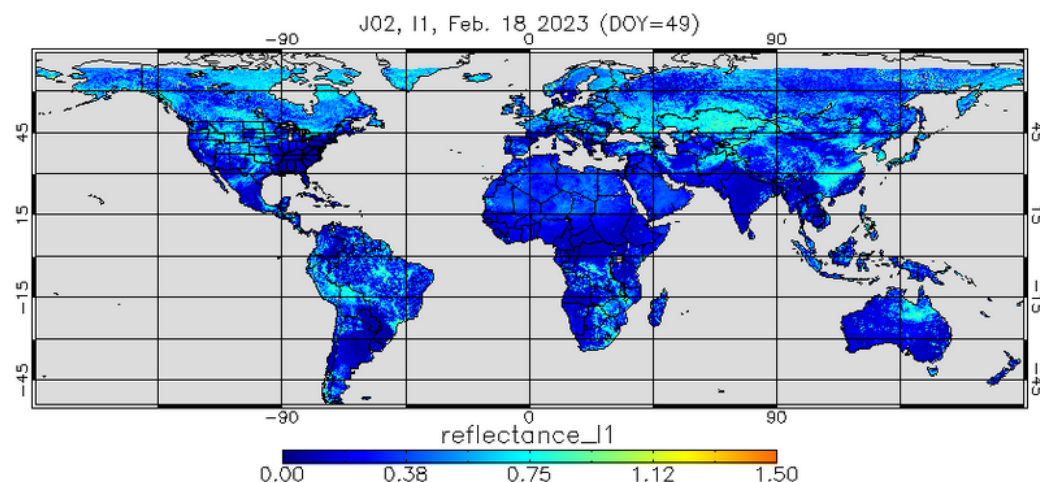
J01 / N20

VGVI.G04.C07.j01.P2023049.RF.I1.png



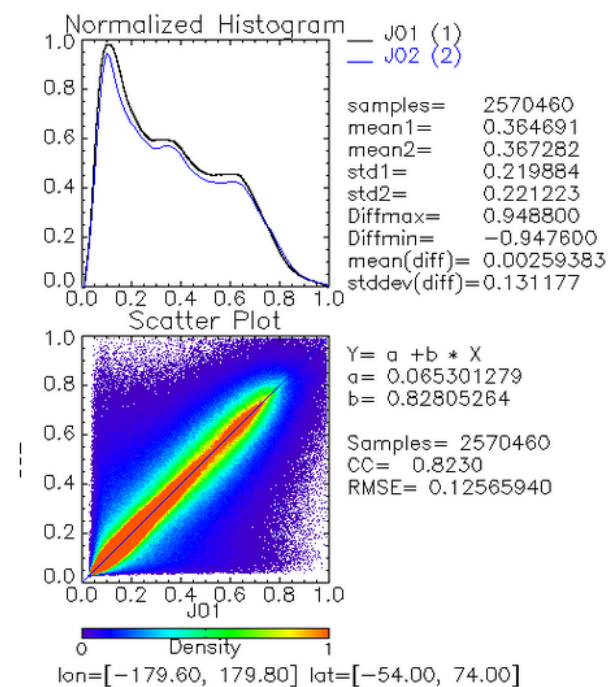
J02 / N21

VGVI.G04.C07.j02.P2023049.RF.I1.png



scatterplot.4km-dailyGVI.I1.j01\_vs\_j02.P2023049.png

I1, 2023049

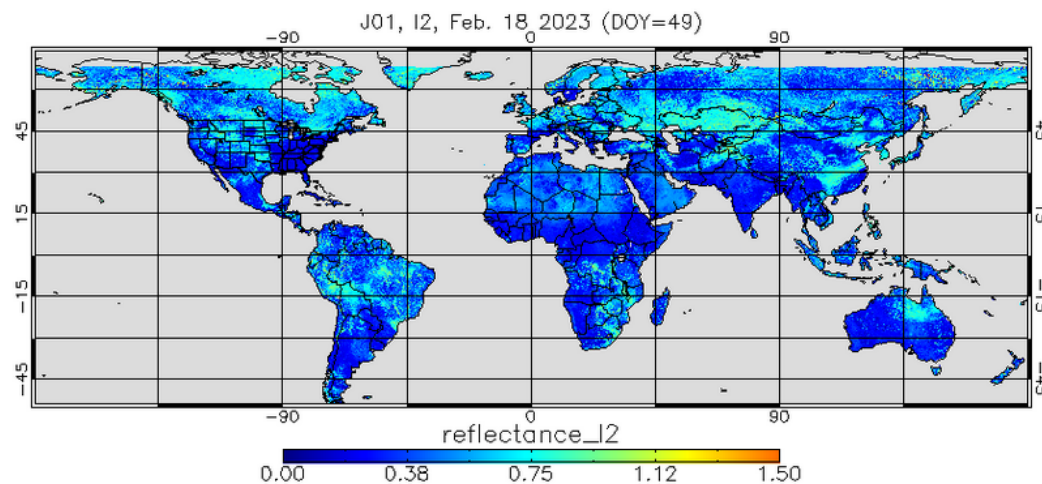


# Compare reflectance: J01 vs J02

## Band I2, 2023 day 49

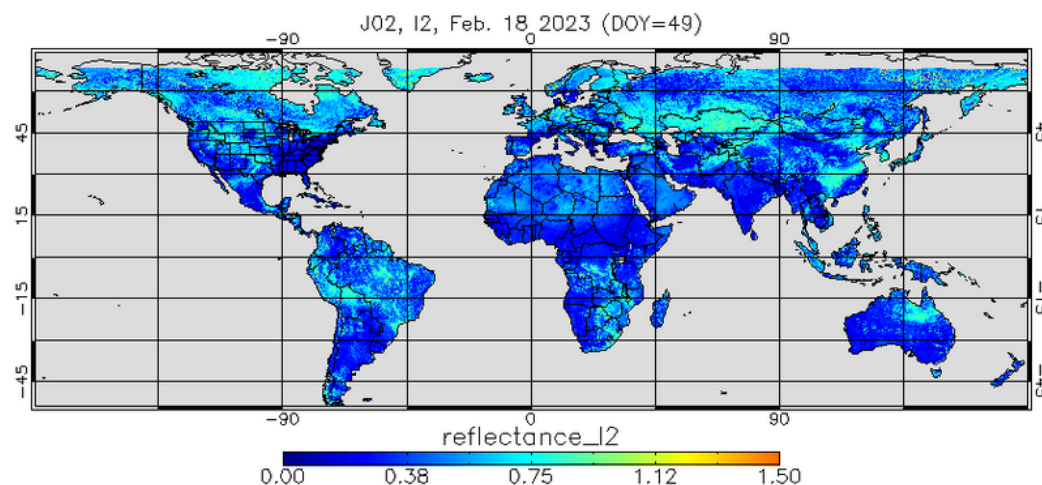
J01 / N20

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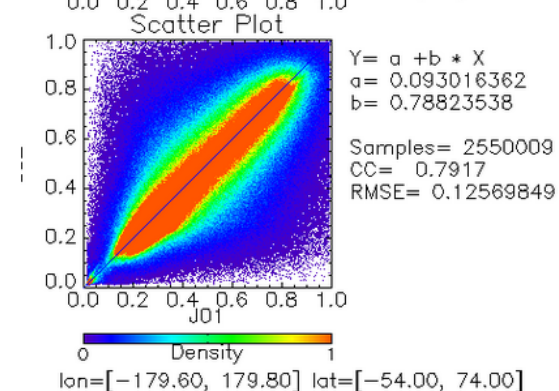
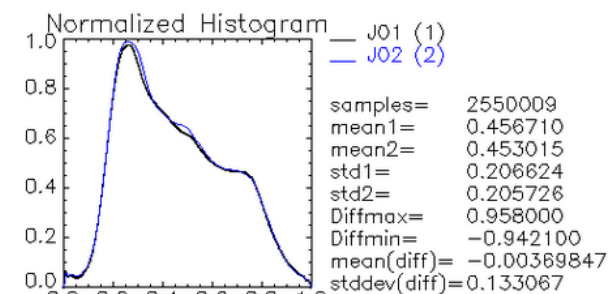
J02 / N21

VGVI.G04.C07.j02.P2023049.RF.I2.png



scatterplot.4km-dailyGVI.I2.j01\_vs\_j02.P2023049.png

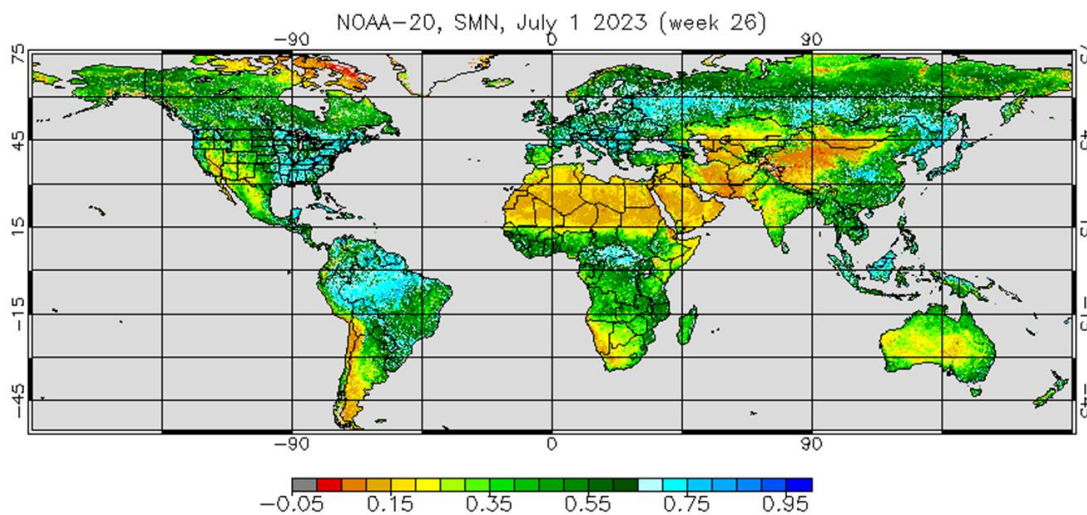
I2, 2023049



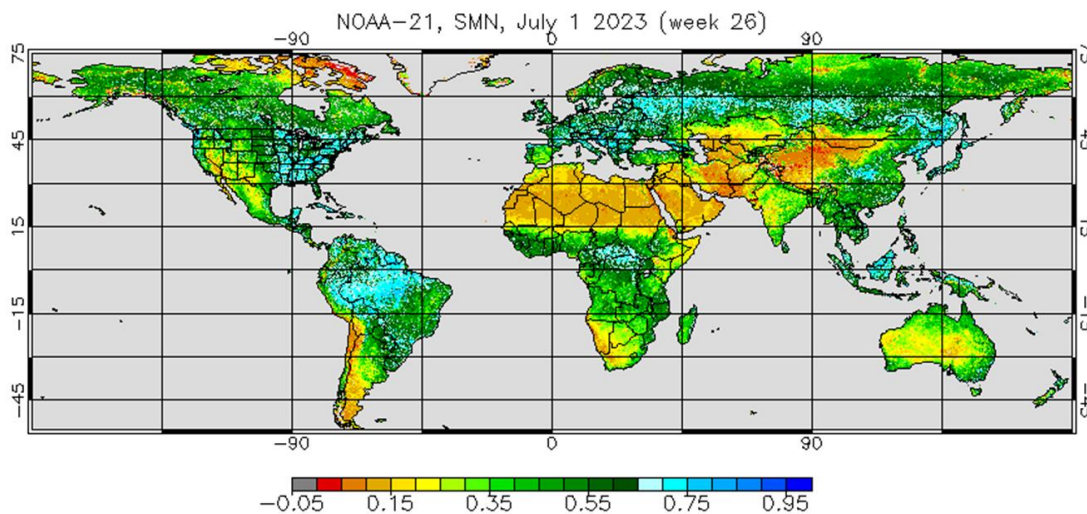
# Compare SMN: J01 vs J02

## July 1, 2023 (week 26)

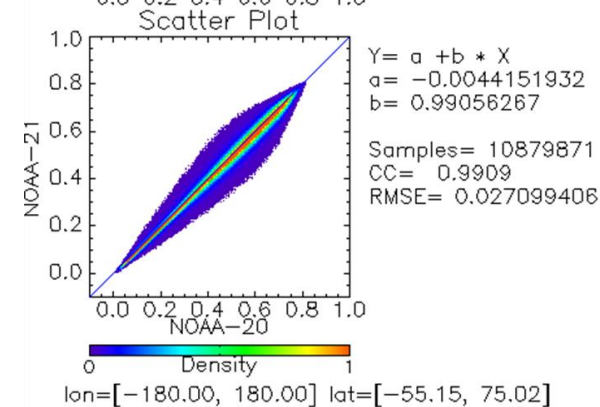
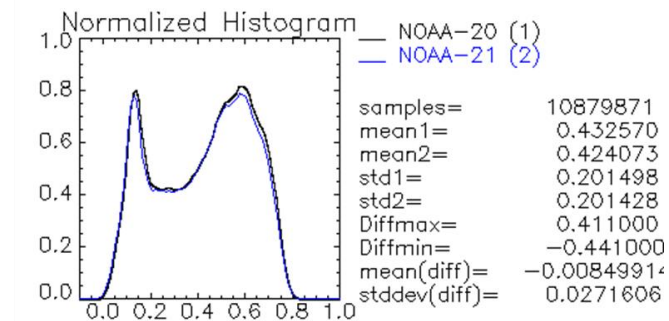
J01 / N20



J02 / N21



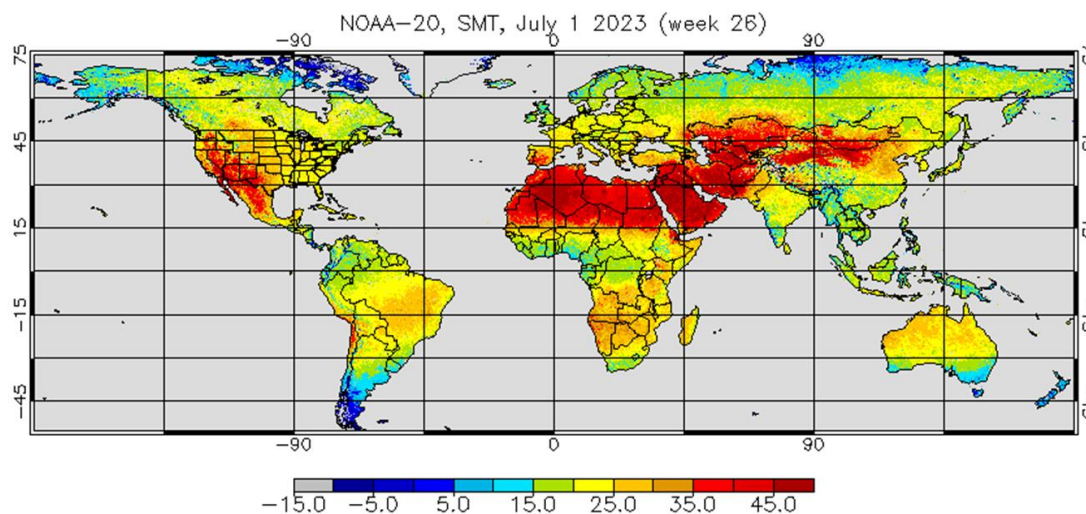
SMN, July 1 2023 (week 26)



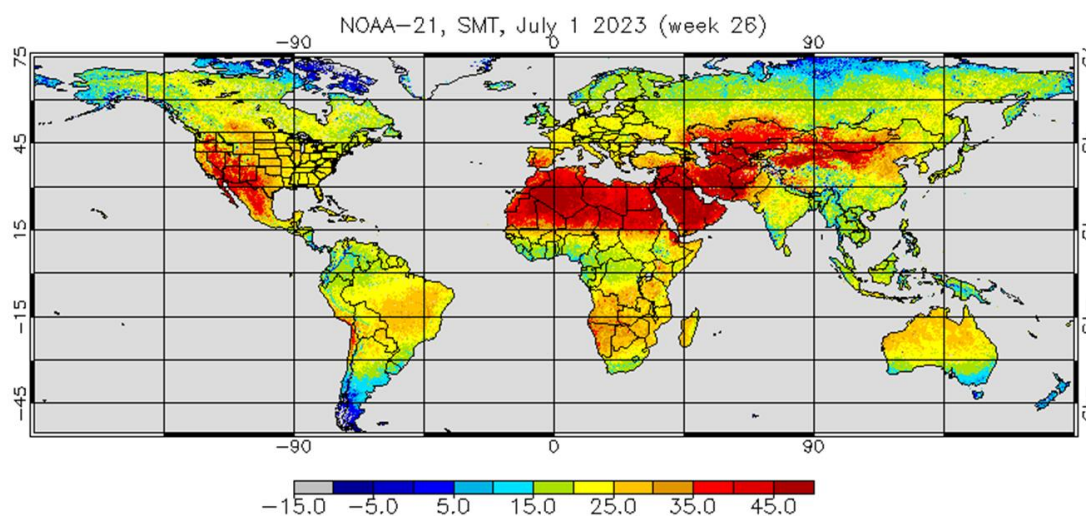
# Compare SMT: J01 vs J02

## July 1, 2023 (week 26)

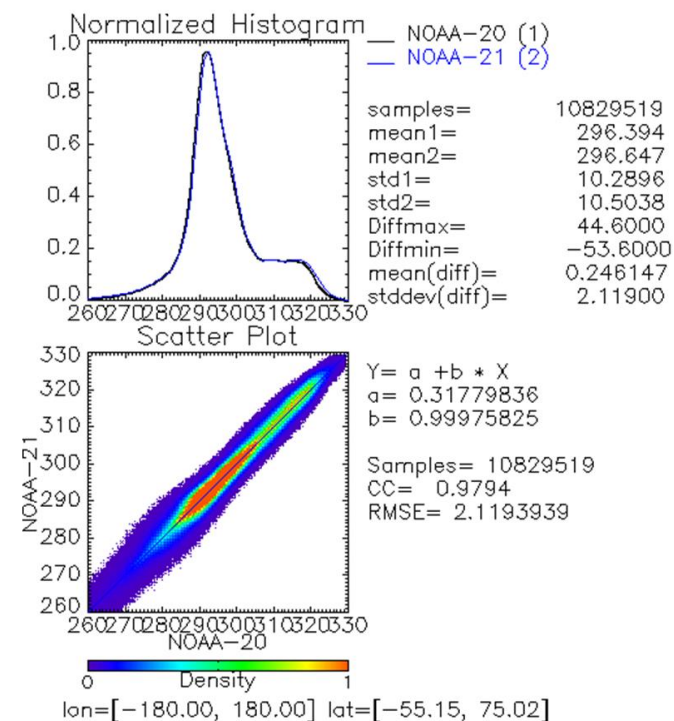
J01 / N20



J02 / N21



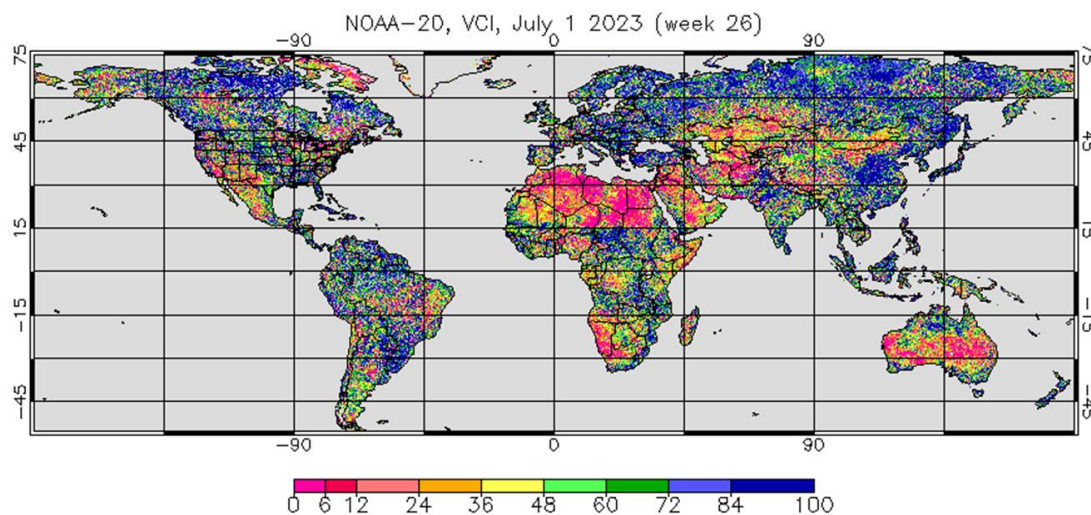
SMT, July 1 2023 (week 26)



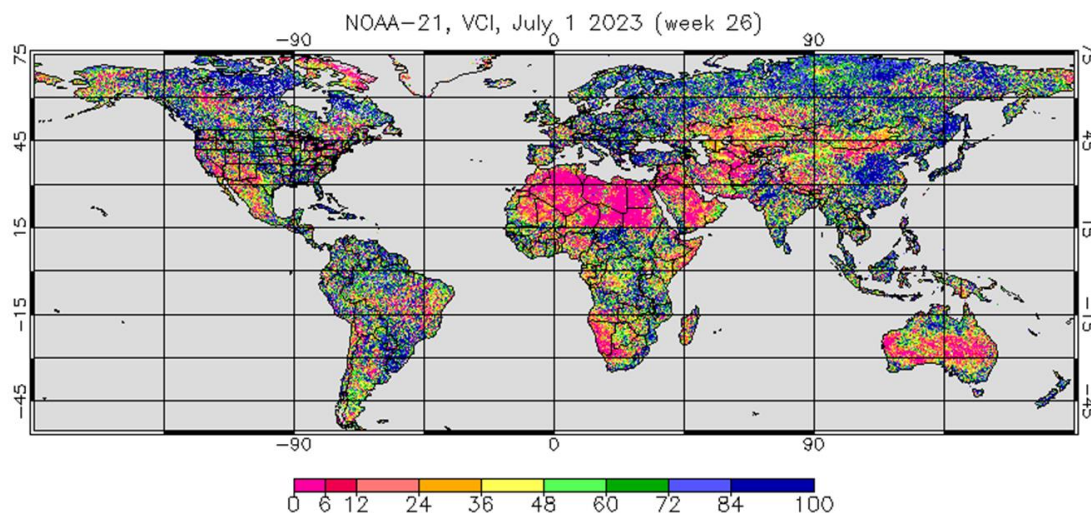
# Compare VCI: J01 vs J02

## July 1, 2023 (week 26)

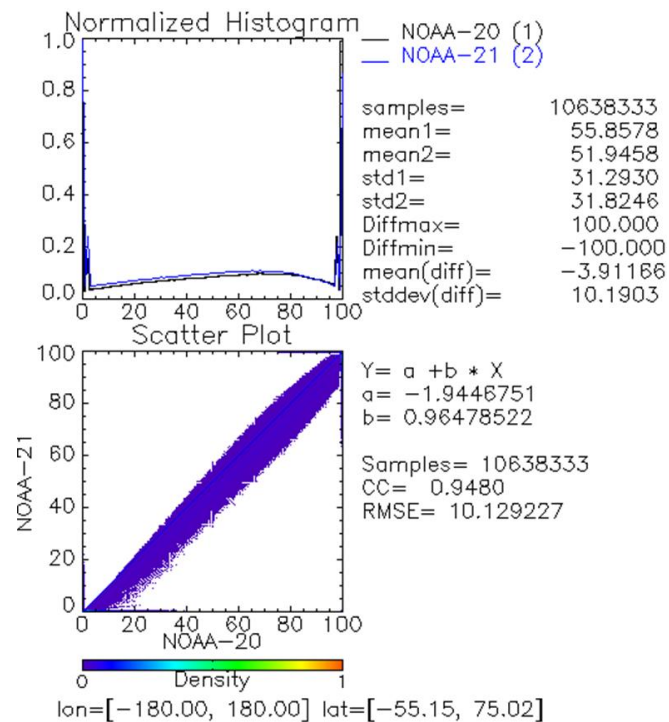
J01 / N20



J02 / N21



VCI, July 1 2023 (week 26)

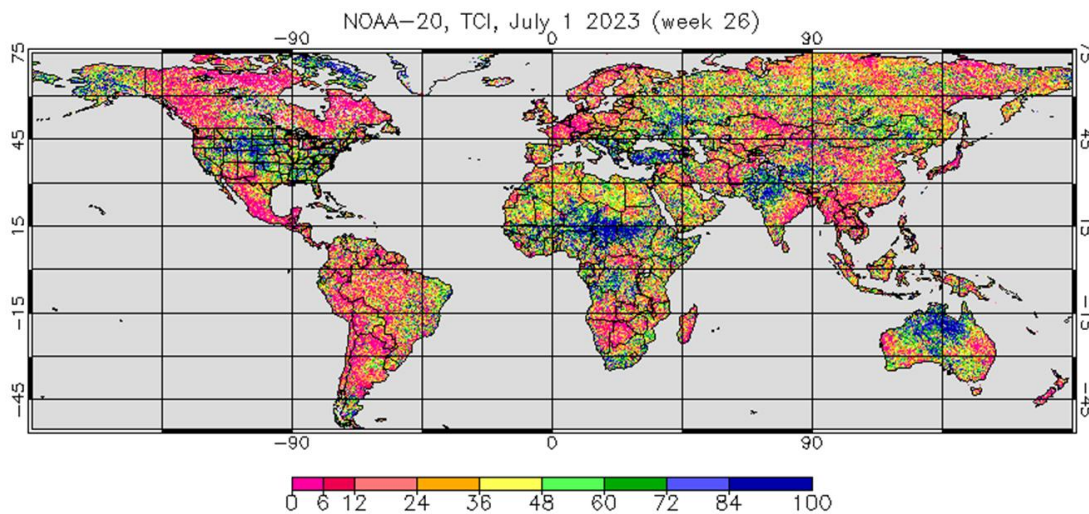




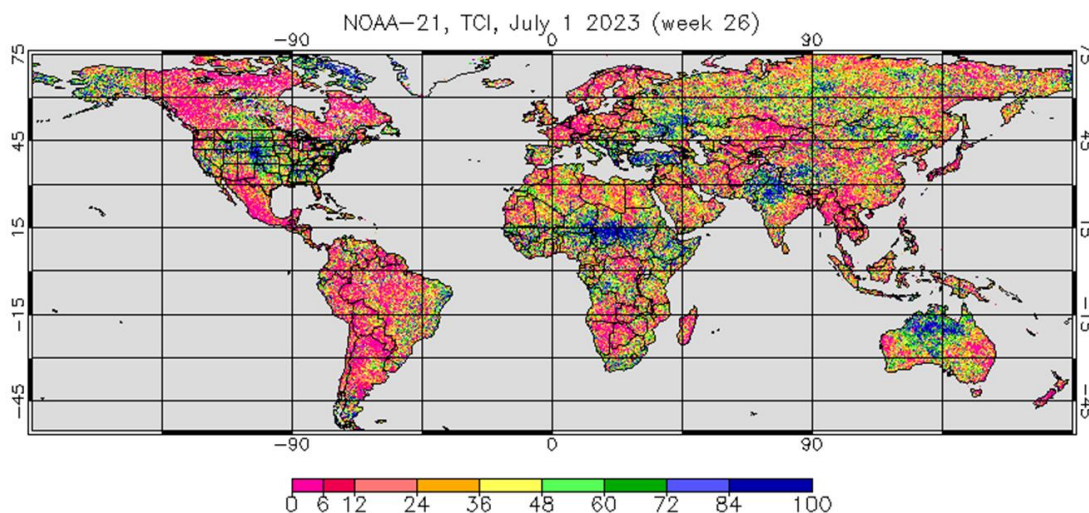
# Compare TCI: J01 vs J02

## July 1, 2023 (week 26)

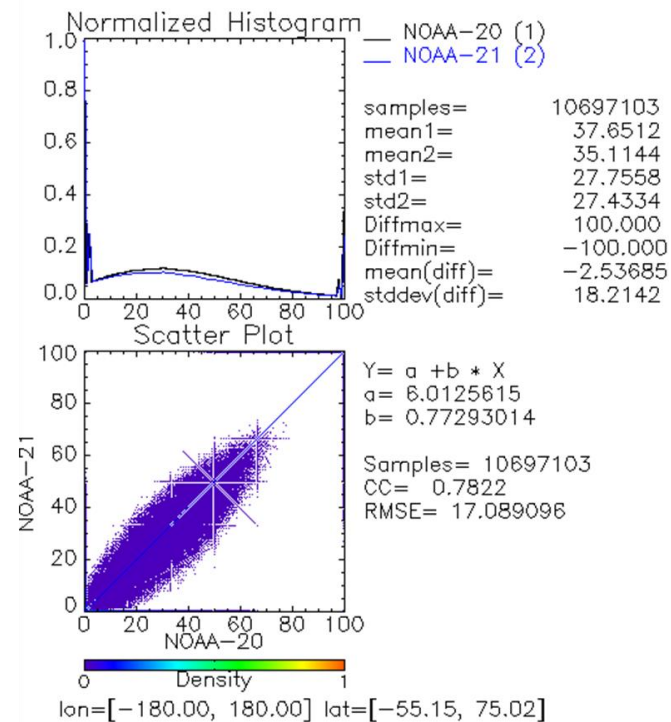
J01 / N20



J02 / N21



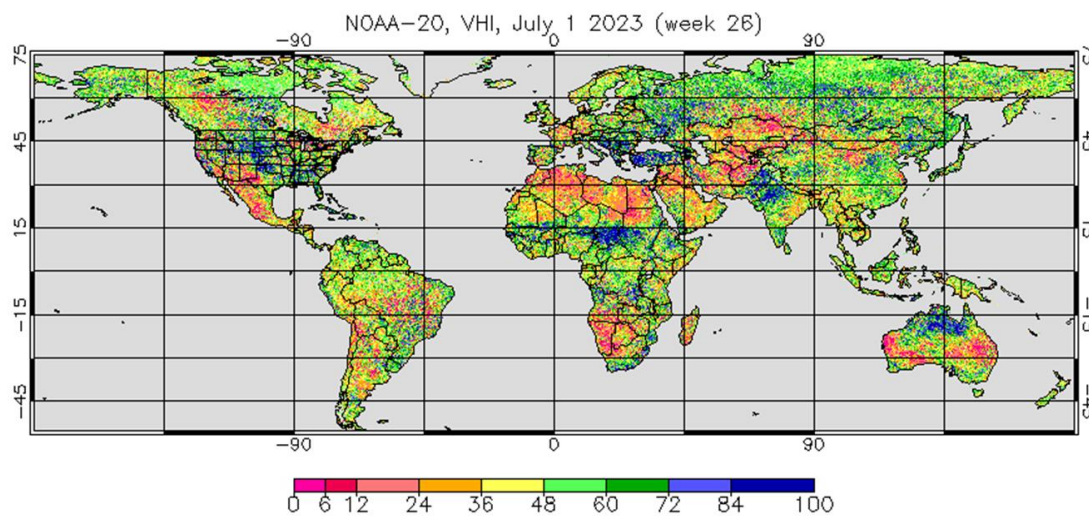
TCI, July 1 2023 (week 26)



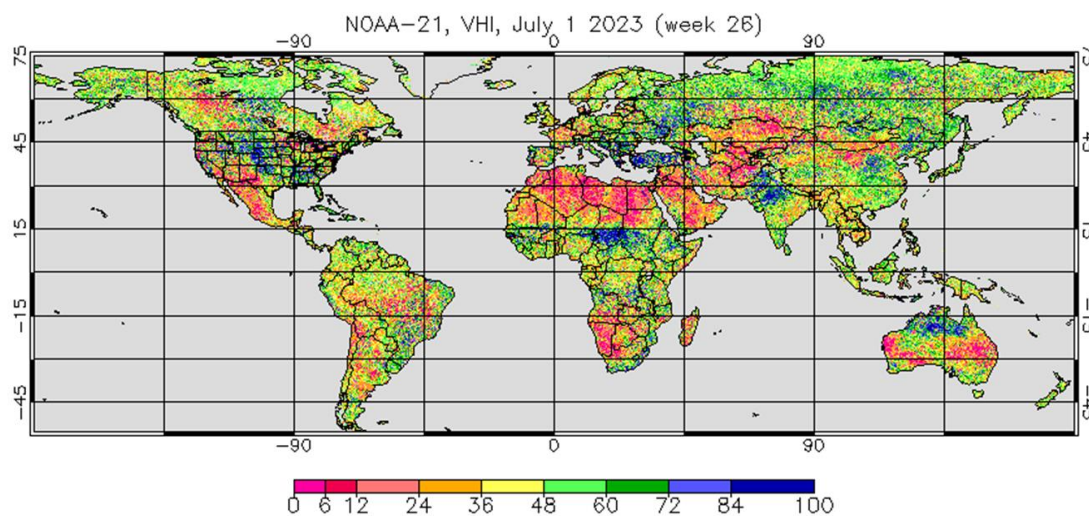
# Compare VHI: J01 vs J02

## July 1, 2023 (week 26)

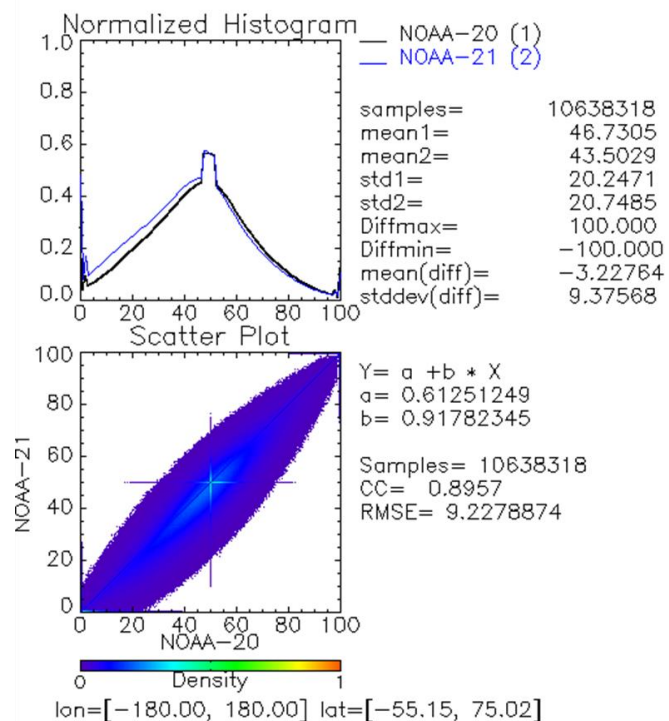
J01 / N20



J02 / N21



VHI, July 1 2023 (week 26)



## 2023 Weekly VH Comparison: NOAA-21/VIIRS vs. NOAA-20/VIIRS

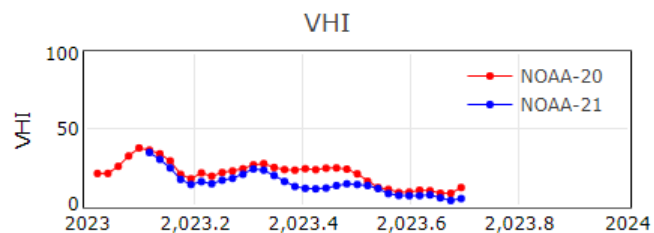
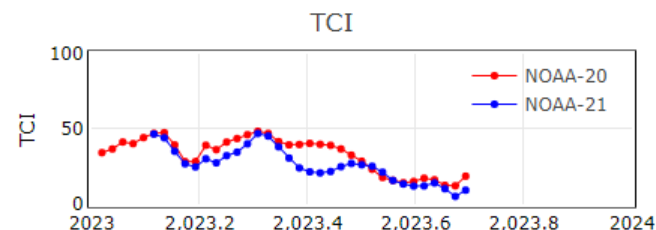
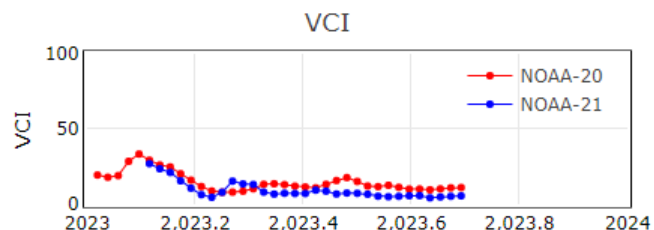
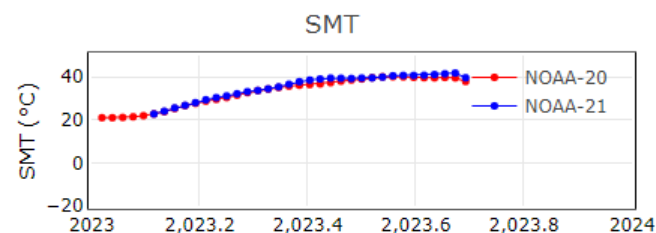
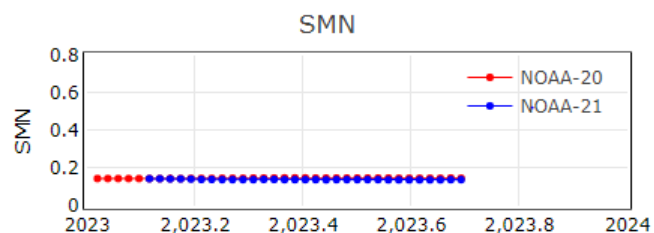
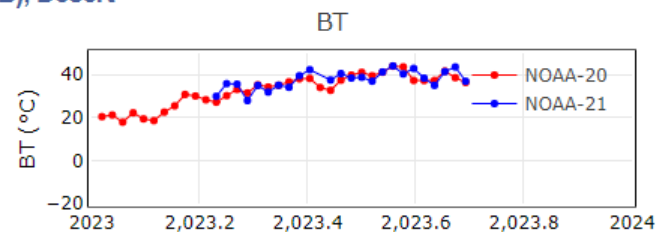
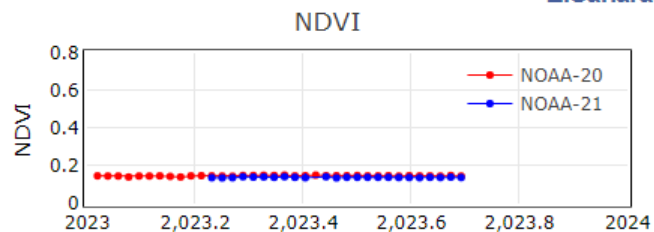
([https://www-dev.star1.nesdis.noaa.gov/smcd/vci/VH/vh\\_targetTimeseries\\_J01vsJ02.php](https://www-dev.star1.nesdis.noaa.gov/smcd/vci/VH/vh_targetTimeseries_J01vsJ02.php))

## STAR - Global Vegetation Health Products : Time Series of selected targets

Data type	Year1	Year2
E. Sahara(LIB)	2023	2023

Time series of this target:

### E.Sahara(LIB), Desert

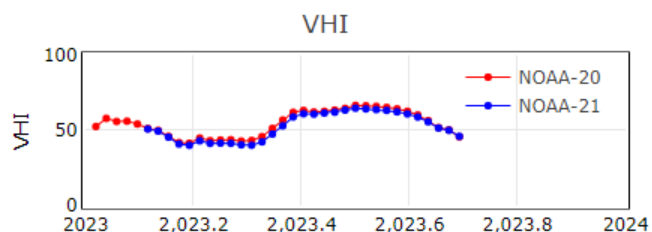
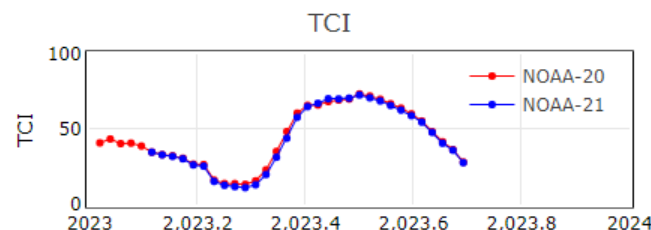
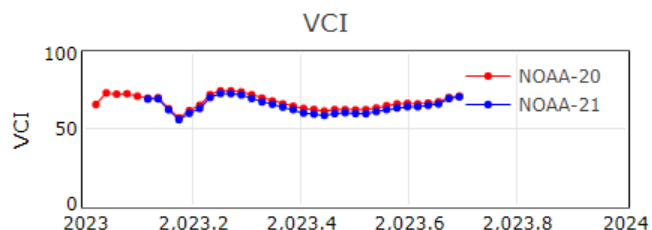
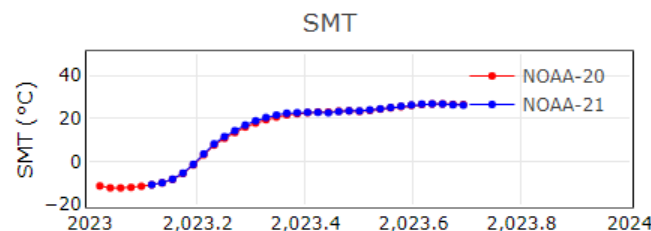
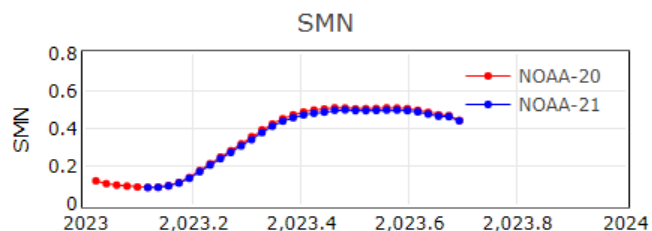
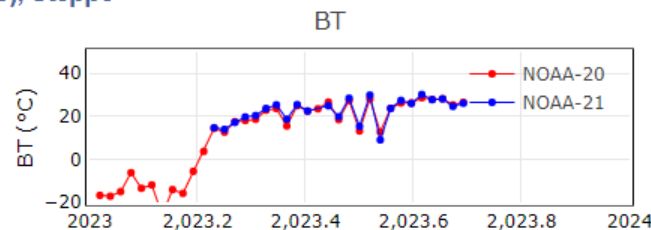
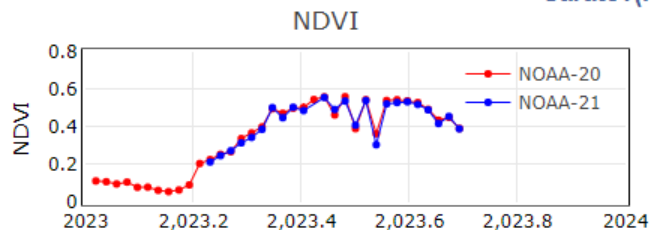


## STAR - Global Vegetation Health Products : Time Series of selected targets

Data type	Year1	Year2
Saratov(RUS)	2023	2023

Time series of this target:

### Saratov(RUS), Steppe

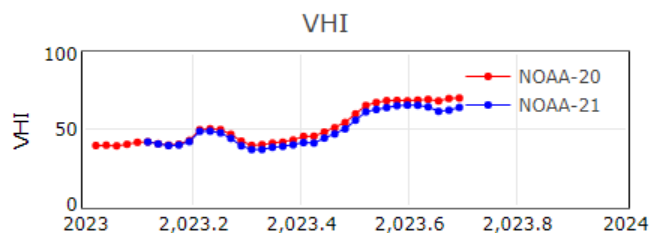
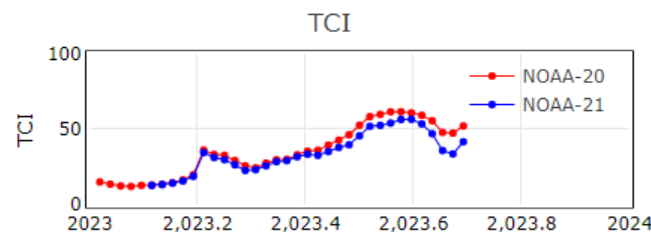
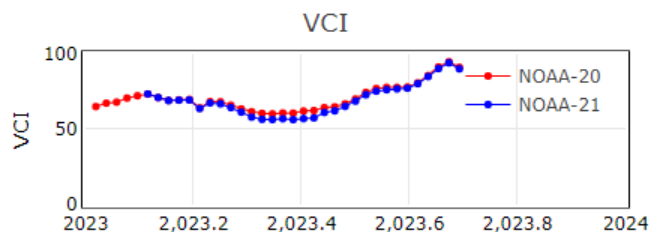
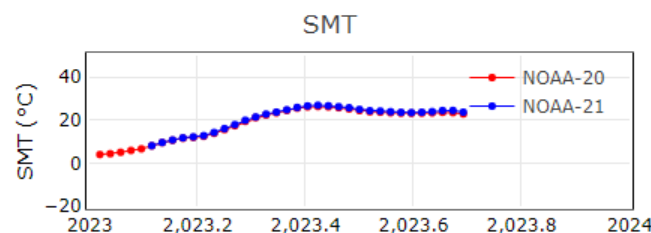
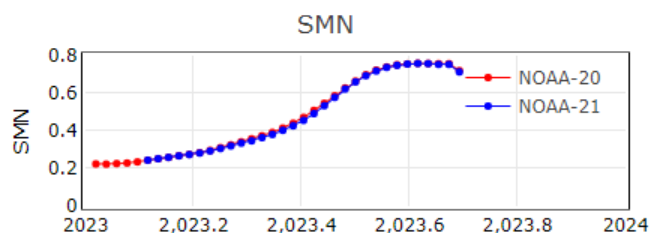
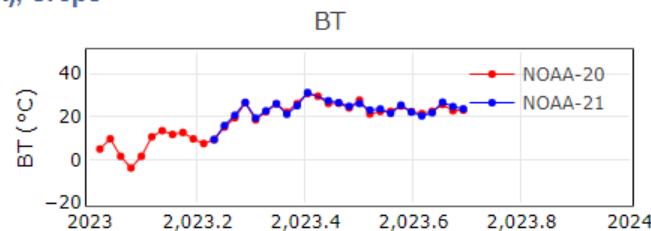
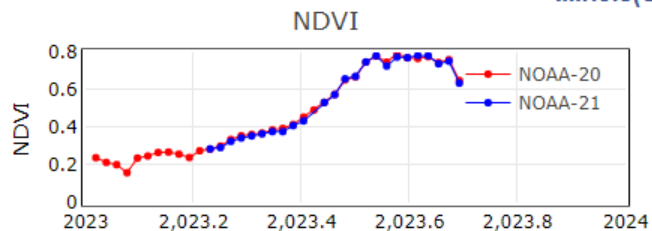


## STAR - Global Vegetation Health Products : Time Series of selected targets

Data type	Year1	Year2
Illinois(USA)	2023	2023

Time series of this target:

### Illinois(USA), Crops

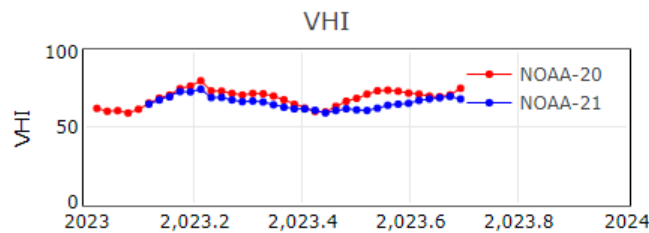
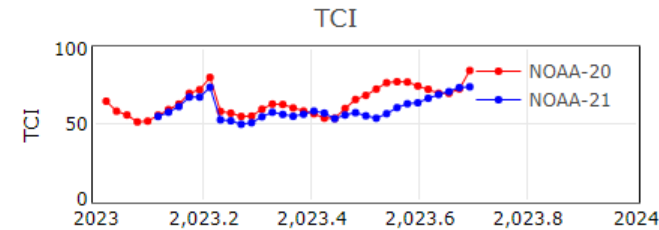
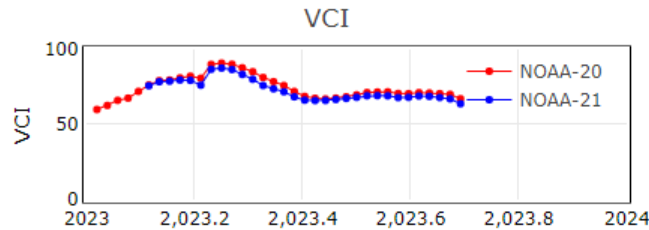
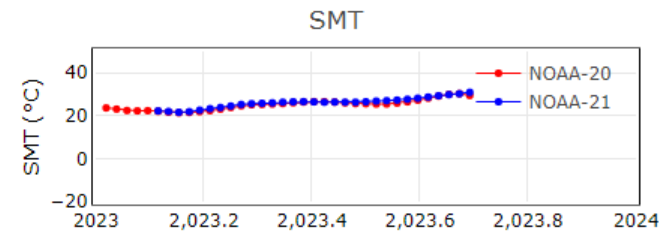
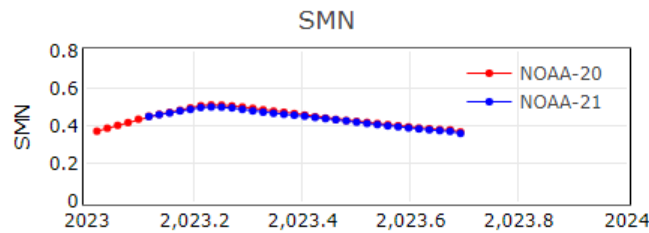
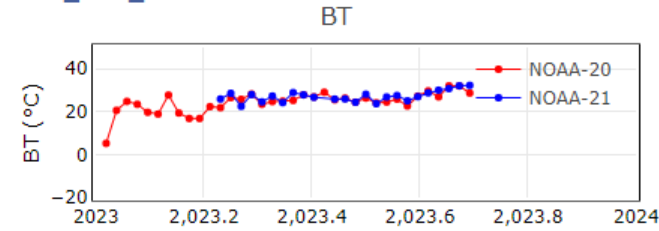
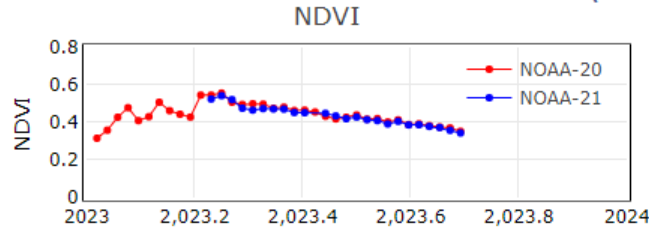


STAR - Global Vegetation Health Products : Time Series of selected targets

Data type	Year1	Year2
S.Quinsland(AUS)	2023	2023

Time series of this target:

S.Quinsland(AUS), Broad\_Leaf\_Forest

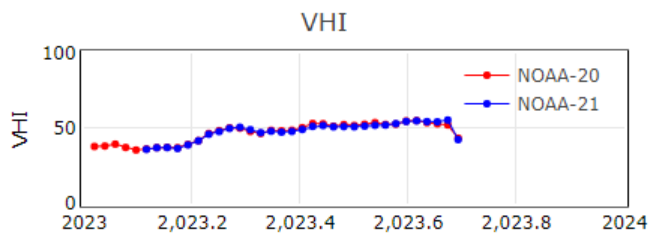
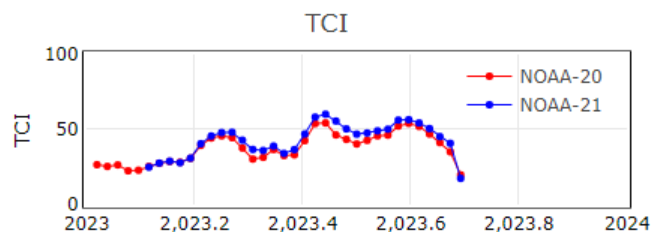
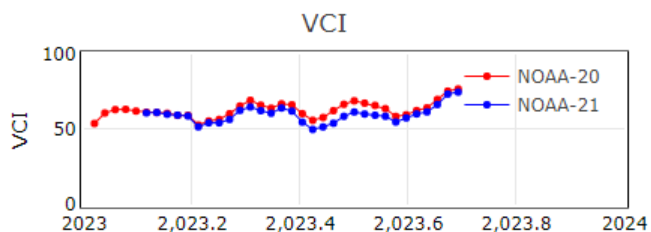
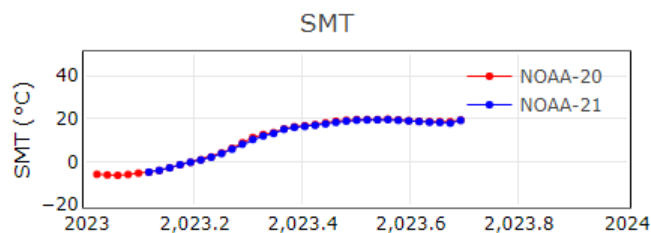
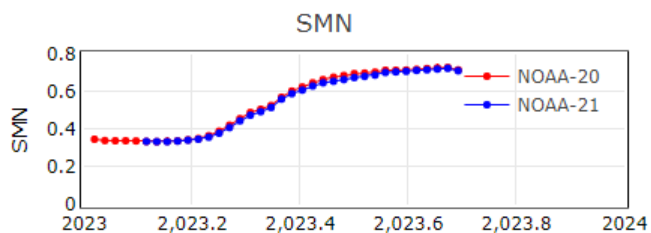
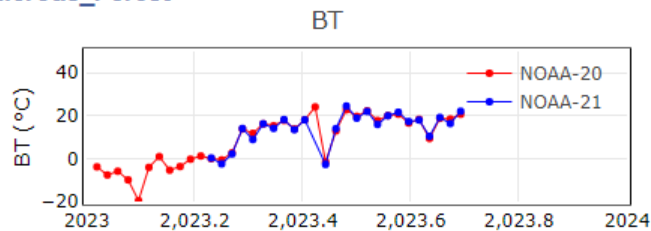
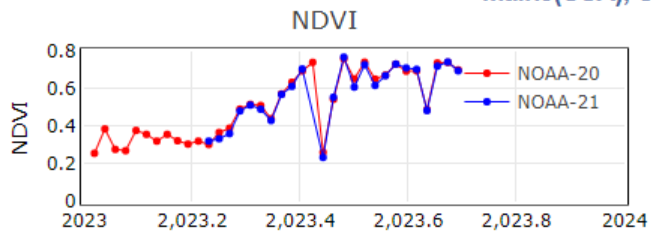


## STAR - Global Vegetation Health Products : Time Series of selected targets

Data type	Year1	Year2
Maine(USA)	2023	2023

Time series of this target:

### Maine(USA), Coniferous\_Forest



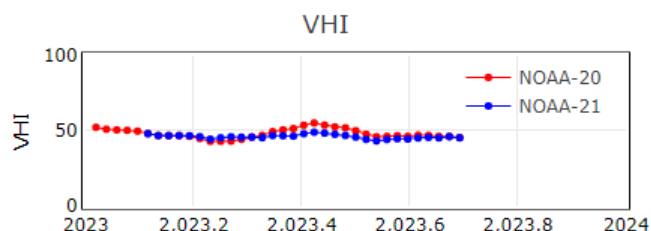
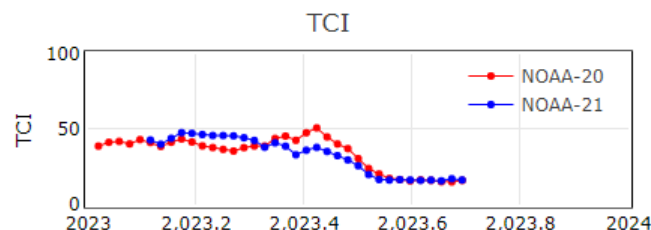
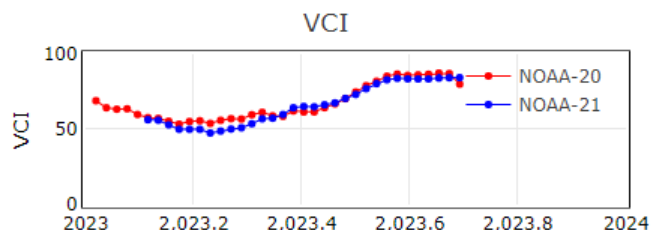
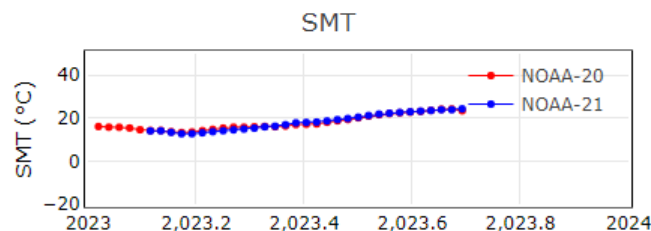
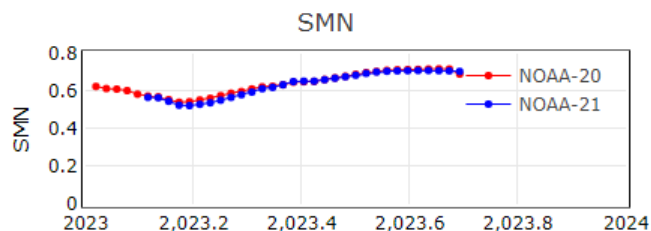
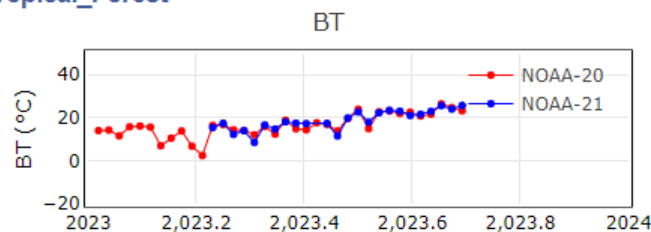
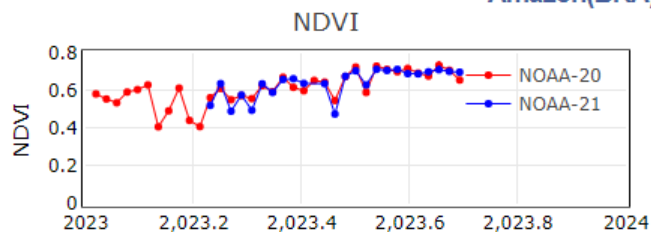


## STAR - Global Vegetation Health Products : Time Series of selected targets

Data type	Year1	Year2
Amazon(BRA)	2023	2023

Time series of this target:

### Amazon(BRA), Tropical\_Forest



**Table 1. Relative differences (%) of VIIRS VH between NOAA-20 and NOAA-21 at 6 sites**

Name	Ecosystem	NDVI	BT4	SMN	SMT	VCI	TCI	VHI
<b>East Sahara (LIB)</b>	Desert	5.98	0.27	5.11	0.28	31.41	22.04	30.95
<b>Saratov (RUS)</b>	Steppe	2.20	0.17	2.59	0.09	3.17	1.95	3.21
<b>Illinois (U.S.A.)</b>	Crops	1.11	0.10	1.30	0.14	2.95	9.49	5.89
<b>South Queensland (AUS)</b>	Broadleaf Forest	1.93	0.28	1.61	0.22	3.68	10.68	7.12
<b>Maine (U.S.A.)</b>	Coniferous Forest	1.17	0.06	1.63	0.07	5.11	5.30	1.50
<b>Amazon (BRA)</b>	Tropical Forest	0.65	0.10	0.74	0.07	1.64	4.13	4.28

**Table 2. Relative differences (%) of VIIRS VH between NOAA-20 and S-NPP at 6 sites**

Name	Ecosystem	NDVI	BT4	SMN	SMT	VCI	TCI	VHI
<b>East Sahara (LIB)</b>	Desert	6.18	0.09	6.08	0.08	116.12	7.65	33.73
<b>Saratov (RUS)</b>	Steppe	1.69	0.07	1.53	0.003	3.89	0.45	2.48
<b>Illinois (U.S.A.)</b>	Crops	0.47	0.12	0.35	0.08	0.61	3.36	1.18
<b>South Queensland (AUS)</b>	Broadleaf Forest	0.22	0.05	0.16	0.06	0.37	4.11	1.75
<b>Maine (U.S.A.)</b>	Coniferous Forest	0.52	0.06	0.21	0.007	1.08	0.36	0.33
<b>Amazon (BRA)</b>	Tropical Forest	0.85	0.0008	1.04	0.0004	3.49	2.39	1.76

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## Quality flag analysis/validation (2-5 slides)

- Defined Quality Flags
  - Variable
  - Description
  - Value
- Quality flag analysis/validation
  - Test / example / ground truth data sets
  - Analysis / validation results
  - Analysis / validation plan

Current QA legend:

Remark = From the least significant bit(LSB):

bit1: 0-valid, 1-invalid

bit2: 0-non-desert, 1-desert

bit3: 0-nonland, 1-land

bit4: 0-noncoastal, 1-coastal

bit5: 0-valid, 1-too cold condition

From early algorithm setup

- Description of processing environment and algorithms used to achieve the maturity stage:
  - Algorithm versions
    - V1: 2013, AVHRR climatology
    - V2: 2017, AVHRR/S-NPP VIIRS combined climatology
    - Planned V3: 500m, long time series, AVHRR/All VIIRS combined clim.
  - Effective dates:
    - Starting from week 17, 2018, blended and temporally consistent VHP data (AVHRR from 1981 to 2012, S-NPP VIIRS from 2013 to 2018, N20 VIIRS 2018 - current) are available from STAR
    - N21 VHP data using AVHRR/All VIIRS combined climatology are being tested internally with current SDR data

- Findings/Issues from {previous-maturity}/last Review
- Improvements since {previous-maturity}/last Review
  - Algorithm Improvements
  - LUT / PCT updates
- Algorithm performance evaluation
  - Validation data sets (type, periods, coverage)
  - Validation strategies / methods
  - Validation results
  - Long term monitoring readiness
- Inter-sensor comparison
  - Compare with S-NPP and NOAA-20
  - Compare with other satellite product

- Required Algorithm Inputs
  - Primary Sensor Data
  - Ancillary Data
  - Upstream algorithms
- Evaluation of the effect of required algorithm inputs
  - Study / test cases
  - Results



- Defined Quality Flags
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# Error Budget (1 slide)

Compare analysis/validation results against requirements, present as a table. Error budget limitations should be explained. Describe prospects for overcoming error budget limitations with future improvements of the algorithm, test data, and error analysis methodology.

Attribute Analyzed	DPS	Requirement/ Threshold	Pre-Launch Performance	On-orbit Performance			Meet Requirement?	Additional Comments
				NOAA-21	NOAA-20	S-NPP		
Accuracy								
Precision								
Uncertainty								

# User Feedback

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations

# Downstream Product Feedback

Algorithm	Product	Downstream Product Feedback - Reports from downstream product teams on the dependencies and impacts

# Risks, Actions, and Mitigations

- Provide updates for the status of the risks/actions identified during the previous maturity review(s); add new ones as needed

Identified Risk	Description	Impact	Action/Mitigation and Schedule

# Documentations (Check List, 1 slide)

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	
Algorithm Theoretical Basis Document (ATBD)	
Algorithm Calibration/Validation Plan	
(External/Internal) Users Manual	
System Maintenance Manual (for ESPC products)	
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	

# Check List - Beta Maturity

Beta Maturity End State	Assessment
<p>Product is minimally validated, and may still contain significant identified and unidentified errors</p>	
<p>Information/data from validation efforts can only be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose</p>	
<p>Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists</p>	

# Check List - Provisional Maturity

Provisional Maturity End State	Assessment
<p>Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from select locations, periods, and associated ground truth or field campaign efforts.</p>	
<p>Product analysis is sufficient to communicate product performance to users relative to expectations (Performance Baseline).</p>	
<p>Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested, and shared with the user community.</p>	
<p>Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.</p>	



# Check List - Validated Maturity

Validated Maturity End State	Assessment
<p>Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).</p>	
<p>Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.</p>	
<p>Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.</p>	
<p>Product is ready for operational use based on documented validation findings and user feedback.</p>	
<p>Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument</p>	

- Cal/Val results summary:
  - Team recommends algorithm Beta maturity
    - Address pre-launch concerns/waivers
    - Caveats

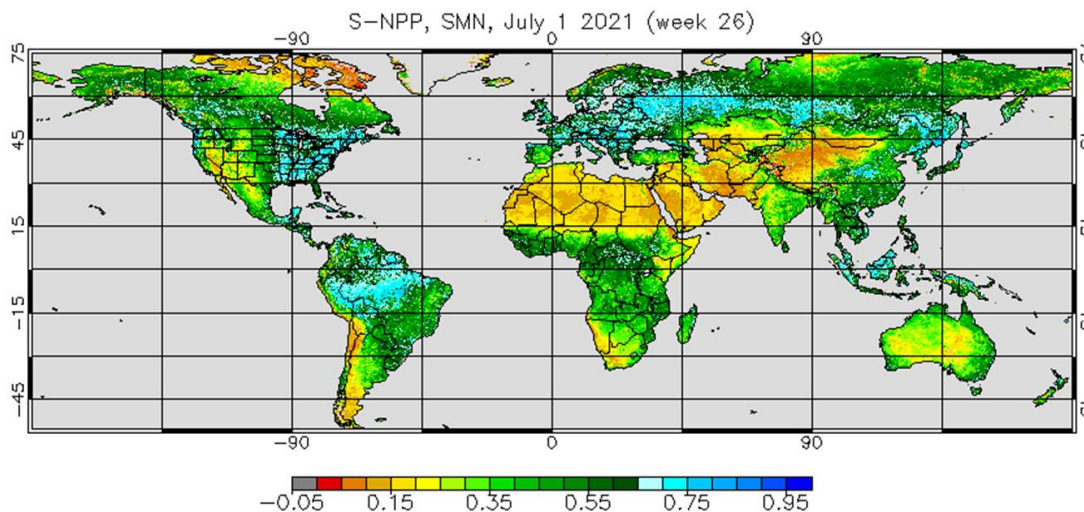
- Lessons learned for NOAA-21 Cal/Val
- Planned improvements
  - Spatial resolution improved to 500m based on 375m VIIRS data
  - Improved computer code for NCCF
  - Enhanced Vegetation Health Index with optimized weighing coefficient
- Future Cal/Val activities / milestones
  - Comprehensive evaluation against users' applications: e.g. crop yield estimate/forecast; fire risk assessment, drought monitoring, etc.
  - Provisional maturity review in April 2024
  - Validated maturity review in April 2025

## Backup Slides

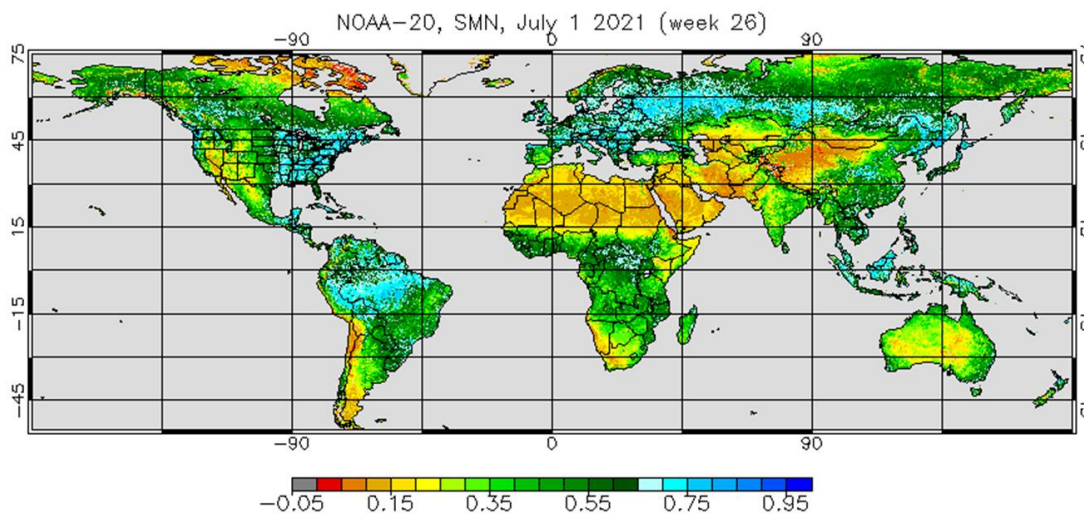
# Compare SMN: NPP vs J01

## July 1, 2021 (week 26)

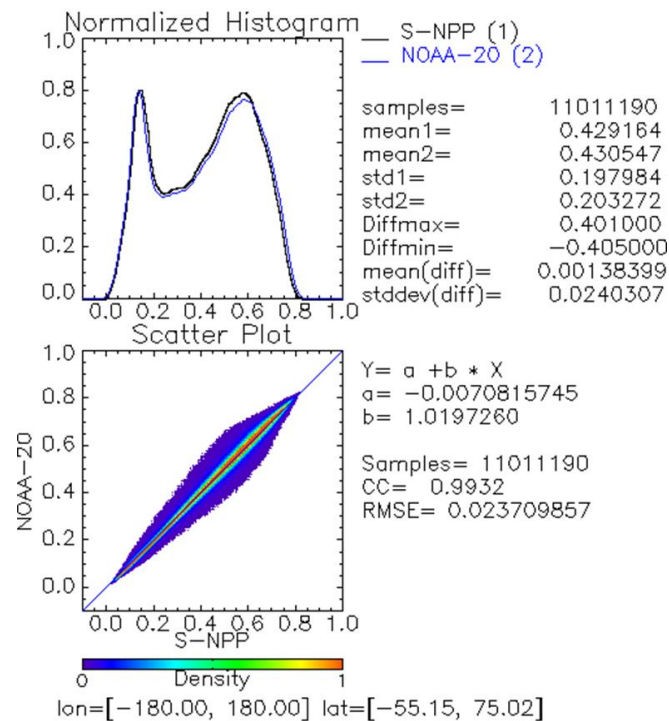
NPP



J01 / N20



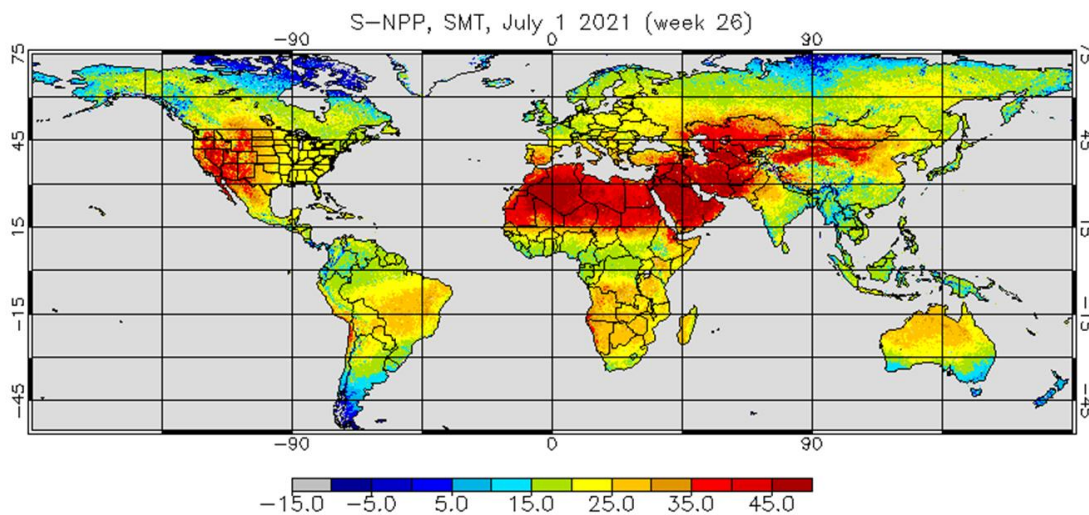
SMN, July 1 2021 (week 26)



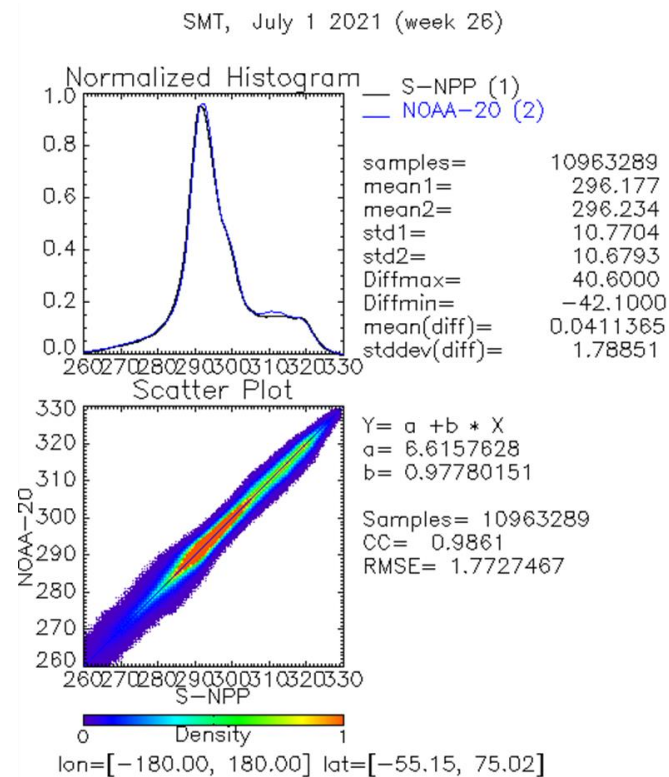
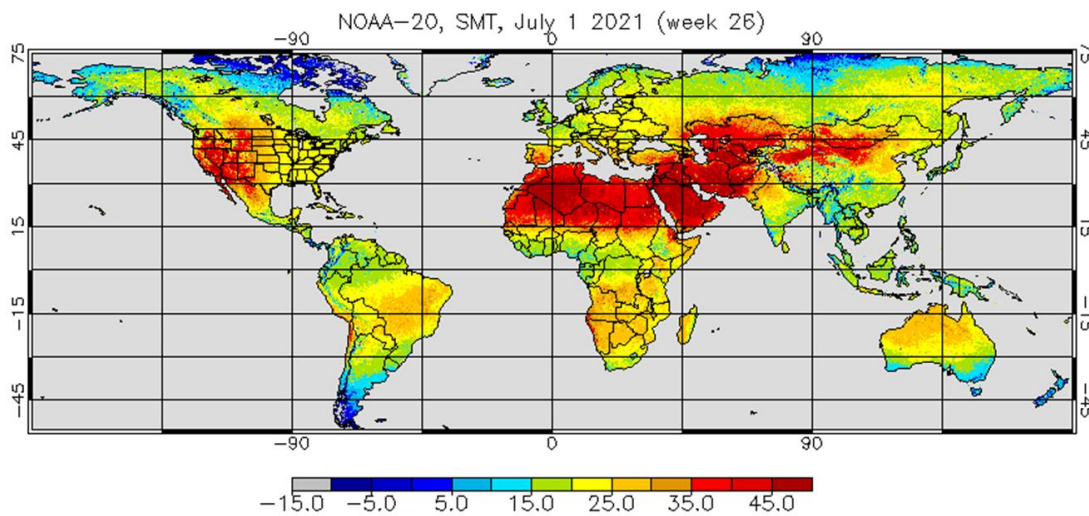
# Compare SMT: NPP vs J01

## July 1, 2021 (week 26)

NPP



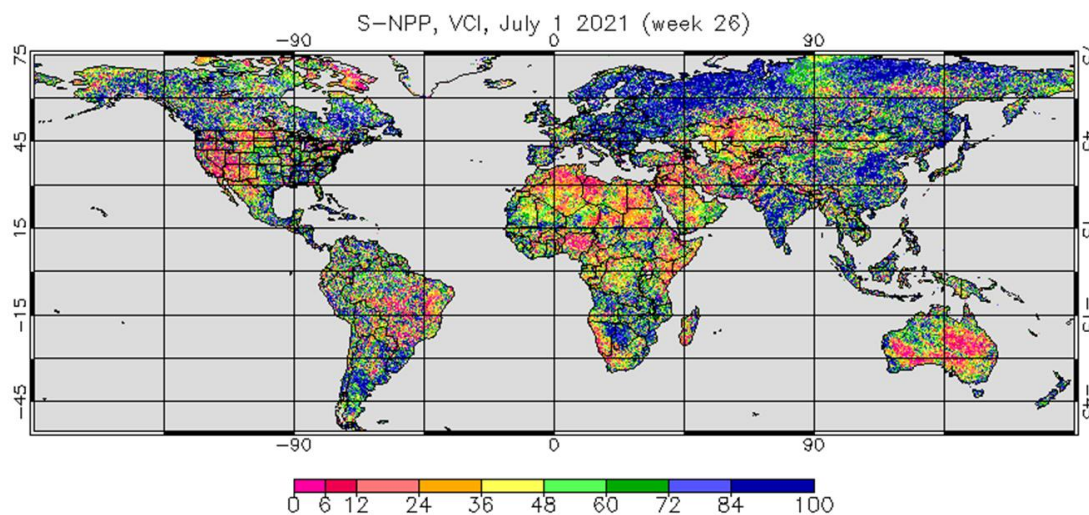
J01 / N20



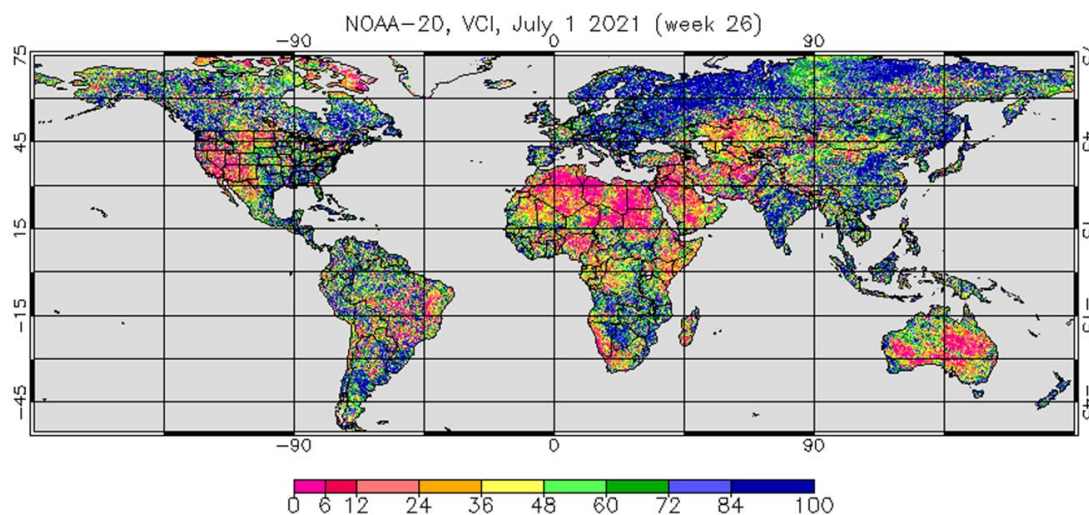
# Compare VCI: NPP vs J01

## July 1, 2021 (week 26)

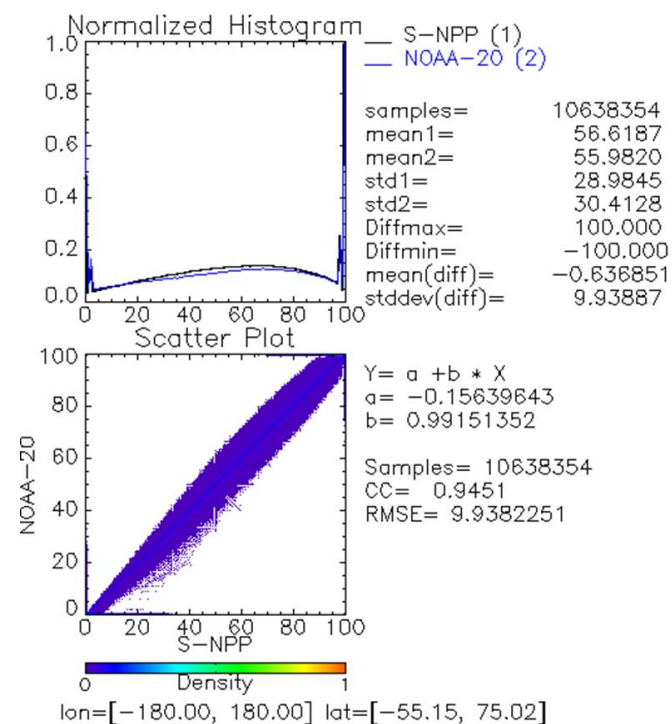
NPP



J01 / N20



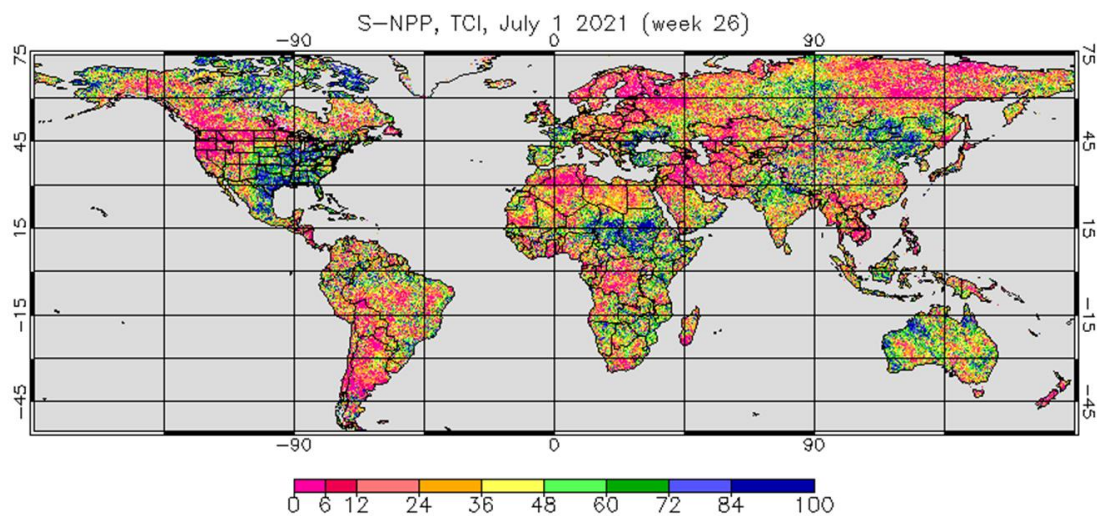
VCI, July 1 2021 (week 26)



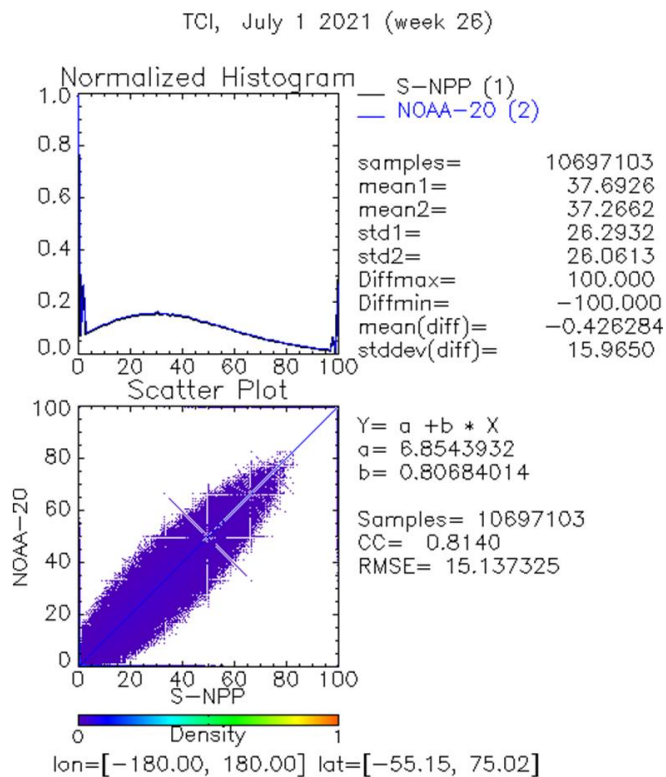
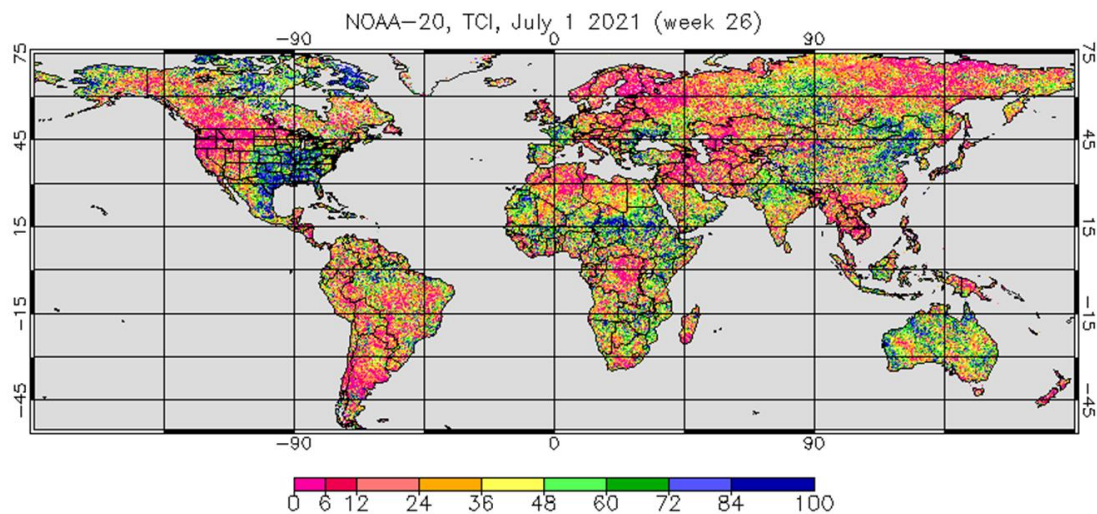
# Compare TCI: NPP vs J01

## July 1, 2021 (week 26)

NPP



J01 / N20

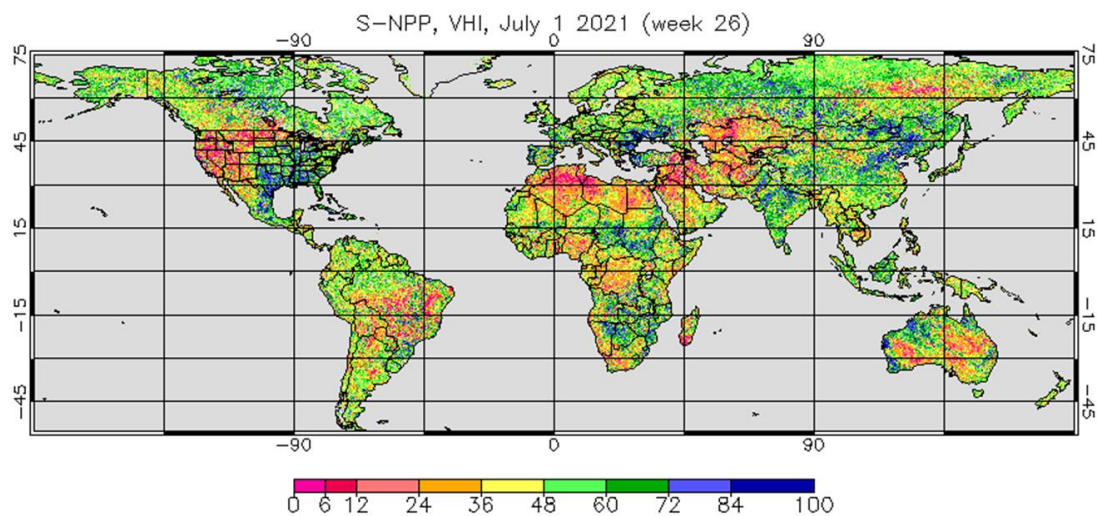




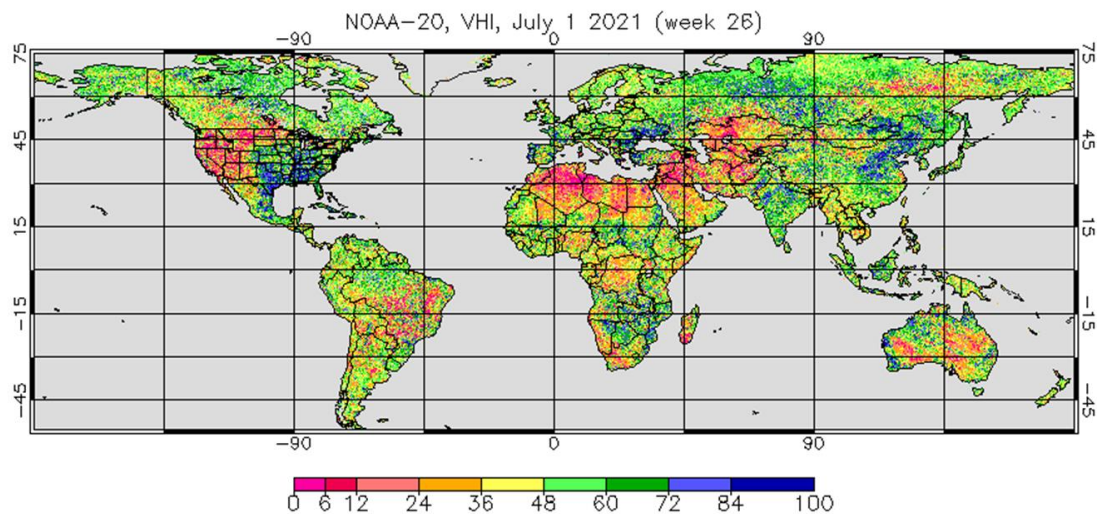
# Compare VHI: NPP vs J01

## July 1, 2021 (week 26)

NPP



J01 / N20



VHI, July 1 2021 (week 26)

