Validated Maturity Science Review For Enterprise Cloud Phase

Presented by Michael Pavolonis

Date: 2019/05/16

JPSS Data Products Maturity Definition

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.

Validated Maturity Review - Entry Criteria

- Product Requirements
- Pre-launch Performance Matrix/Waivers
- 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/EDRs feedback
- Risks, Actions, Mitigations
  - Potential issues, concerns
- Path forward
- Summary

Validated Maturity Review - Exit Criteria

- 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 Validated Maturity Slide Package addressing review committee's comments for:
  - Cal/Val Plan and Schedules
  - Product Requirements
  - Validated Maturity Performance
  - Risks, Actions, Mitigations
  - Path forward

VALIDATED MATURITY REVIEW MATERIAL

Outline

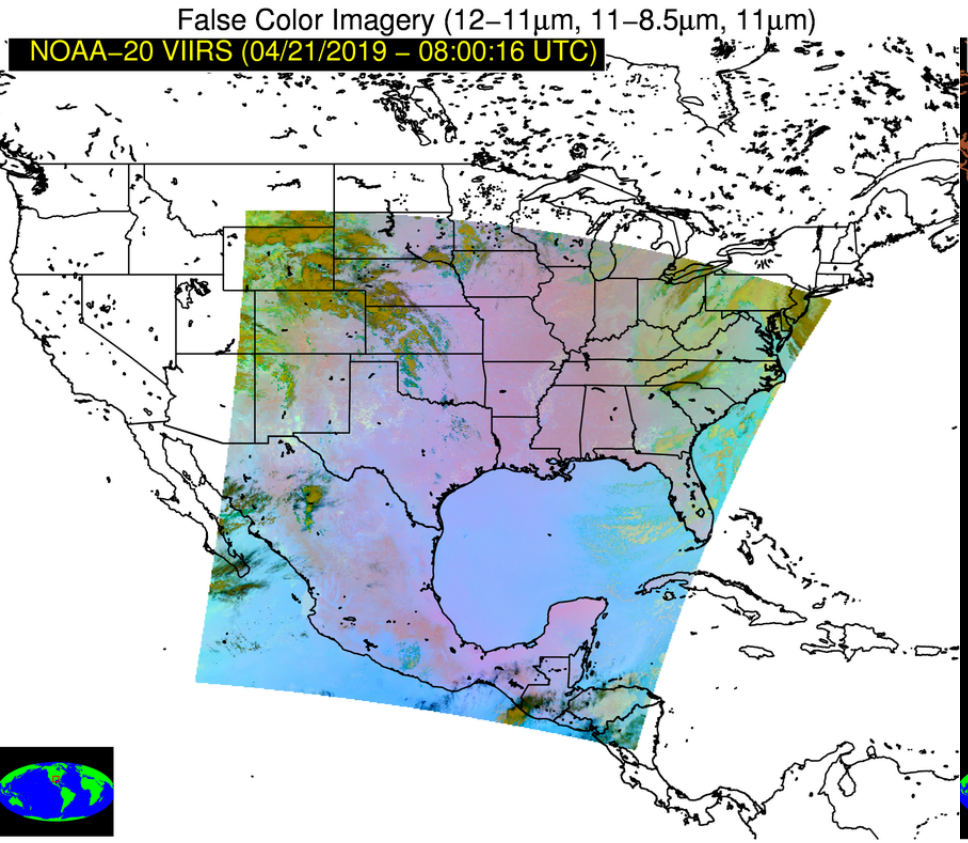
- Algorithm Cal/Val Team Members
- Product Overview/Requirements
- Evaluation of algorithm performance to specification requirements
  - Algorithm version, processing environment
  - Evaluation of the effect of required algorithm inputs
  - Quality flag analysis/validation
  - Error Budget
- User Feedback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

Algorithm Cal/Val Team Members

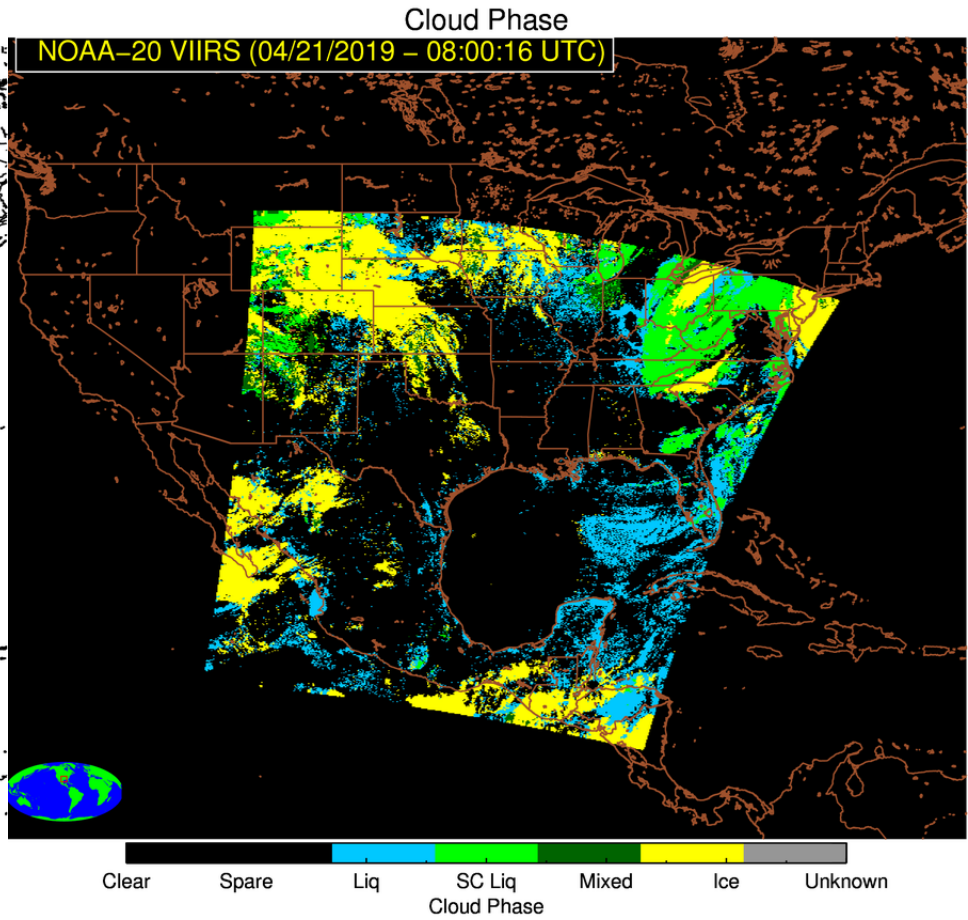
Name	Organization	Major Task
Michael Pavolonis	NESDIS/STAR	Cloud Phase PI
Jason Brunner	UW-CIMSS	Algorithm development and validation
Corey Calvert	UW-CIMSS	Algorithm development and validation
William Straka	UW-CIMSS	ASSISTT integration
Shuang Qiu	OSPO	Product Area Lead

NOAA-20 Cloud Phase Example

False Color Imagery



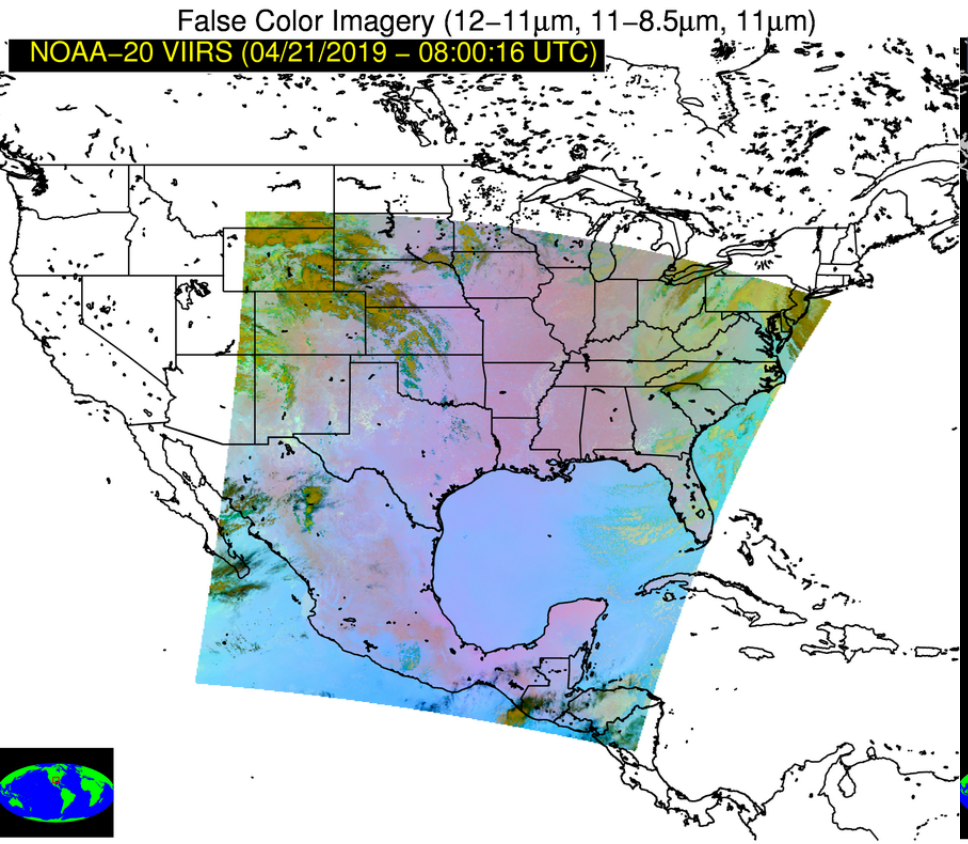
Cloud Phase EDR



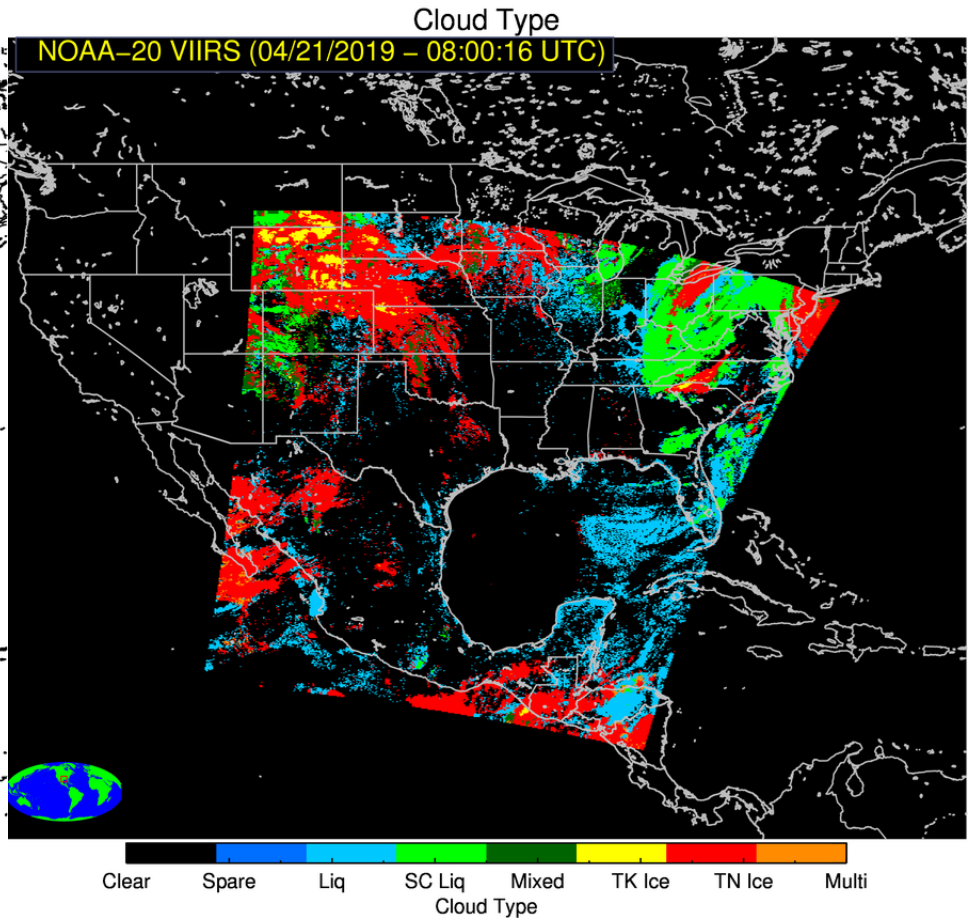
Liquid Supercooled Mixed Ice

NOAA-20 Cloud Type Example

False Color Imagery



Cloud Type EDR



Liquid Supercooled Mixed Thick Ice Thin Ice Multilayered Ice

Requirements: Cloud Phase

Product performance requirements from JPSS L1RD supplement (threshold) versus observed/validated/JERD Vol. II

Attribute	JPSS L1RD	JERD
Geographic coverage	Global – whenever detectable clouds are present	Global – wherever detectable clouds are present
Vertical Coverage	Cloud top	Cloud top
Vertical Cell Size	Cloud top	Cloud top
Horizontal Cell Size	0.8 km	0.8 km
Mapping Uncertainty	4 km	4 km
Measurement Range	Water, ice, or mixed	Liquid, supercooled liquid, mixed, ice, and unknown
Measurement Accuracy	Ocean, Day, COT > 1.0: 94% Land, Day, COT > 1.0: 90% Ocean, Night, COT > 1.0: 85% Land, Night, COT > 1.0: 88%	80% correct detection
Measurement Precision	NA	NA

Requirements: Cloud Type

Product performance requirements from JPSS L1RD supplement (threshold) versus observed/validated/JERD Vol. II

Attribute	L1RD	JERD
Geographic coverage	NA	Global – wherever detectable clouds are present
Vertical Coverage	NA	Cloud top
Vertical Cell Size	NA	Cloud top
Horizontal Cell Size	NA	0.8 km
Mapping Uncertainty	NA	4 km
Measurement Range	NA	Liquid, supercooled liquid, mixed, opaque ice, optically thin single layer ice, optically thin ice with underlying cloud layers, and unknown
Measurement Accuracy	NA	60% correct detection
Measurement Precision	NA	NA
Measurement Uncertainty	NA	60% correct detection

Previous Reviews

- **Beta:** no review

- **Provisional (Oct 2018):** Compared to Calipso, accuracy is 0.57 - 0.70 (requirement is 0.6). Very good characterization of the performance, including identification of conditions when VIIRS cloud phase works well and doesn't. Good comparison results against GOES-16 showing good agreement except in Mixed phase.

NDE/STAR VIIRS ECP Production Status

Algorithm	Suomi NPP	NOAA-20
August 2018 DAP February 2018 Science Code delivery (~~v2r0~~)	**STAR** Systematic production since June, 2018 **NDE** **In Ops String since Jan 2019**	**STAR** Systematic production since June, 2018 **NDE** **In Ops String since 7 March 2019**
Jan/Feb 2019 DAP August 2018 Science Code delivery (v2r1)	**Delivered to NDE in late March 2019**	**Delivered to NDE in late March 2019**
Late 2019 DAP Science Code delivery date TBD (v2r2)	**Delivery and development in progress** Delivery schedule provided by ASSISTT	**Delivery and development in progress** Delivery schedule provided by ASSISTT

Evaluation Methodology

Version of NOAA-20 cloud phase EDR evaluated: v2r0

Algorithm changes since Provisional: none

Evaluation Methods:

1. Validation against NASA CALIOP (lidar)

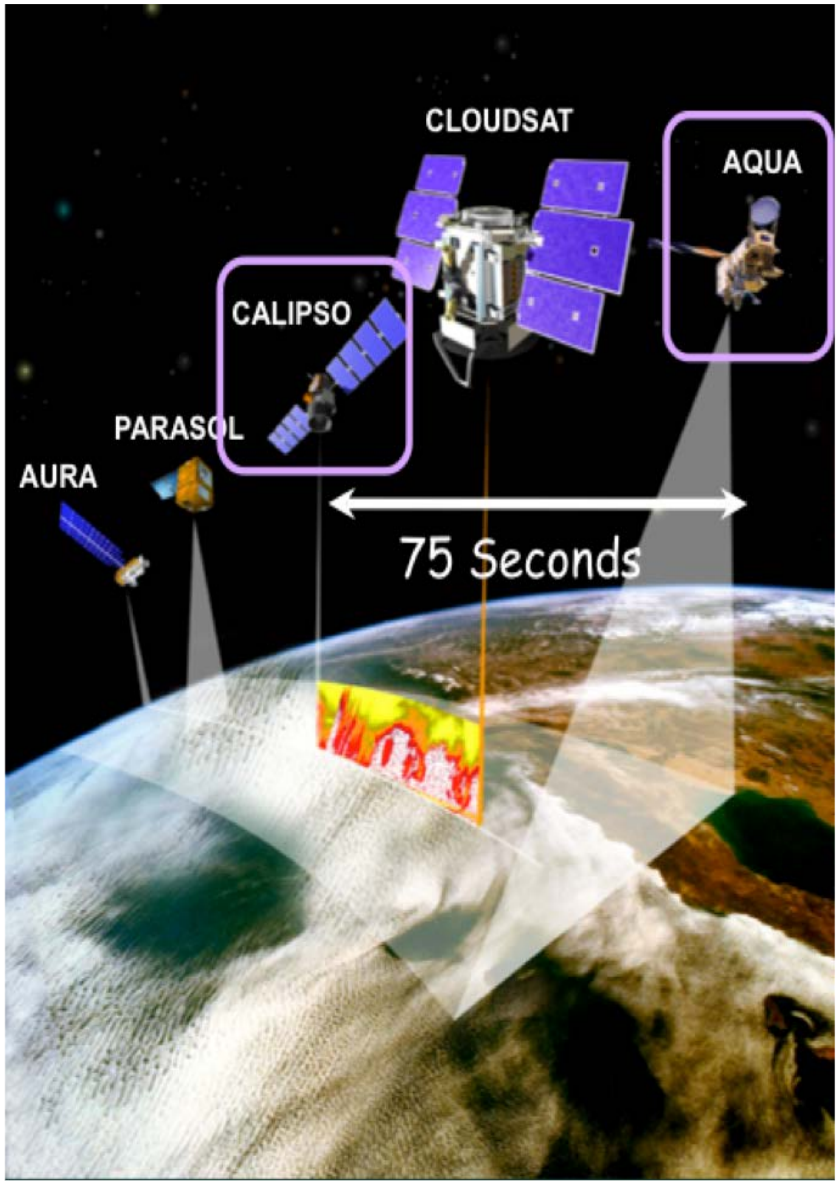
1. Comparison NDE ECP and GOES-16 phase from the GOES-R ground system

1. Visual S-NPP vs. NOAA-20 comparisons

COMPARISON TO CALIOP

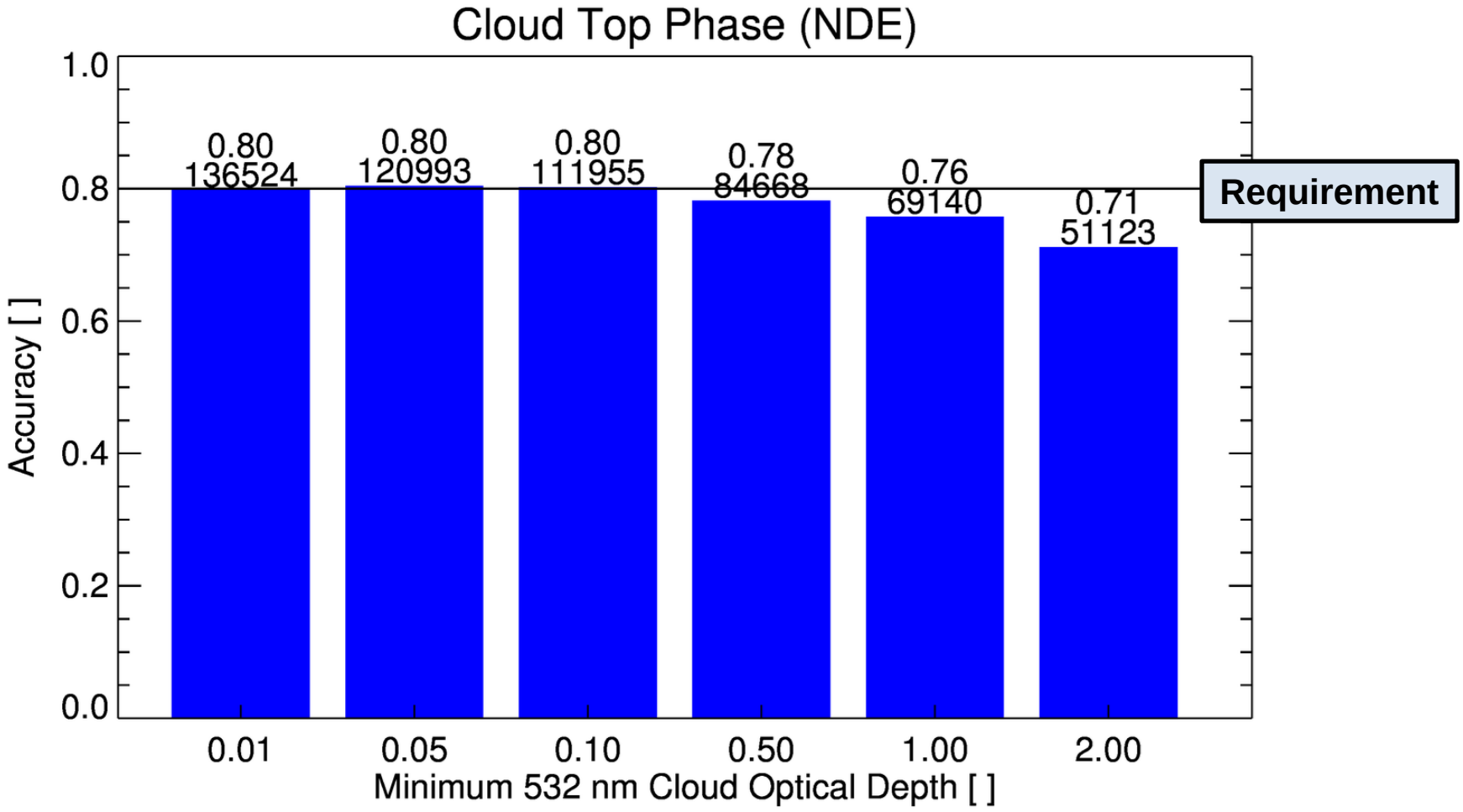
CALIOP vs. NOAA-20

- CALIOP is a lidar, with depolarization, on board the CALIPSO satellite in the NASA A-Train.
- The CALIOP 1 and 5 km vertical feature mask products are merged to derive the cloud phase of the highest cloud layer with CALIOP 532 nm optical depth > 0.01
- 5 days of CALIOP and NOAA-20 matchup data are used (NH summer, fall, and winter conditions are captured)
- Validation analysis is a function of the CALIOP 532 nm cloud optical depth



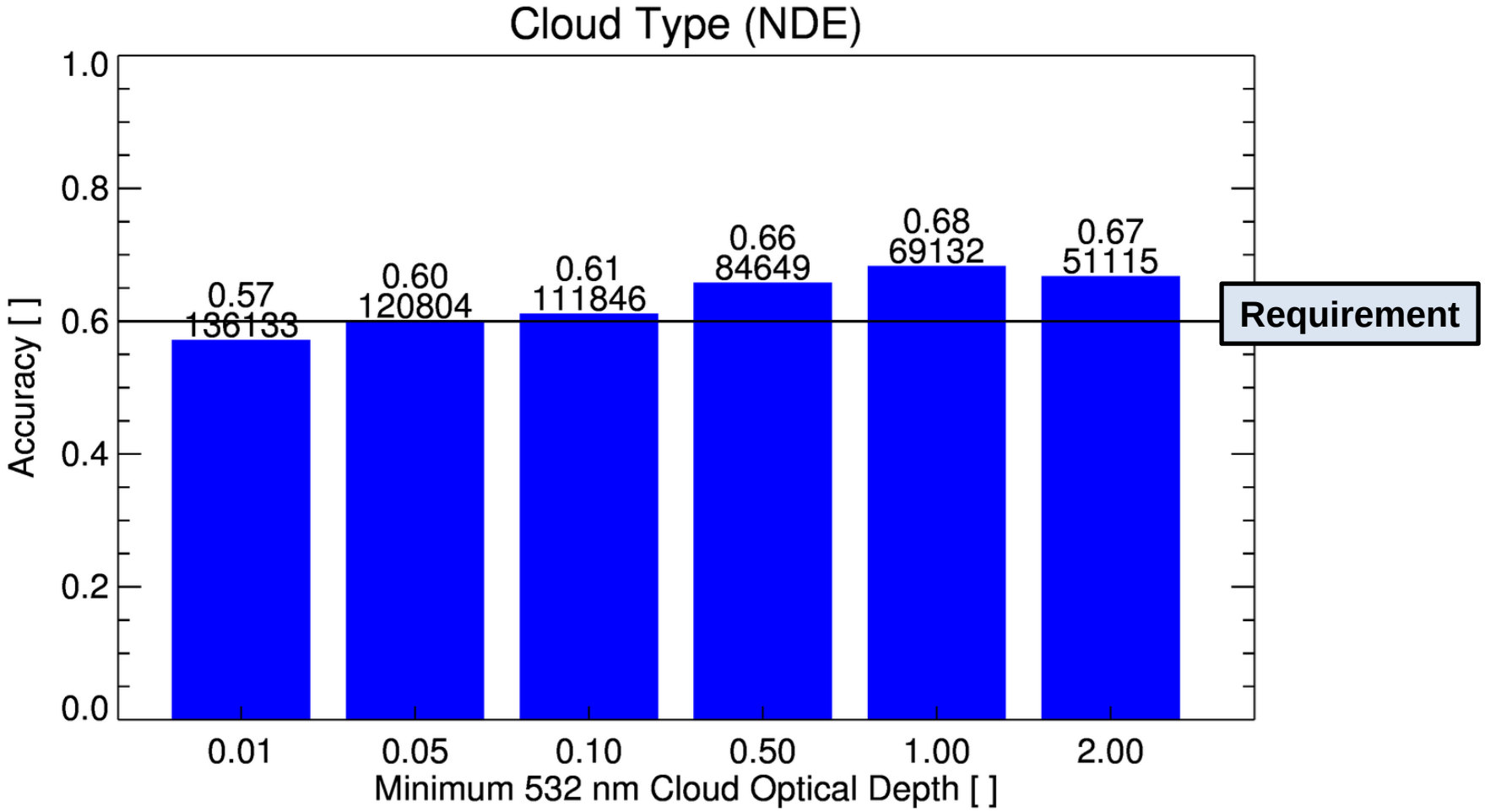
CALIOP vs. NOAA-20: Cloud Phase

When clouds with an optical depth of 0.10 (common definition of detectable clouds for passive measurements) or greater are considered, the NOAA-20 cloud top phase product meets the accuracy specification. Classification of optically thick clouds mid-level clouds remains a challenge.

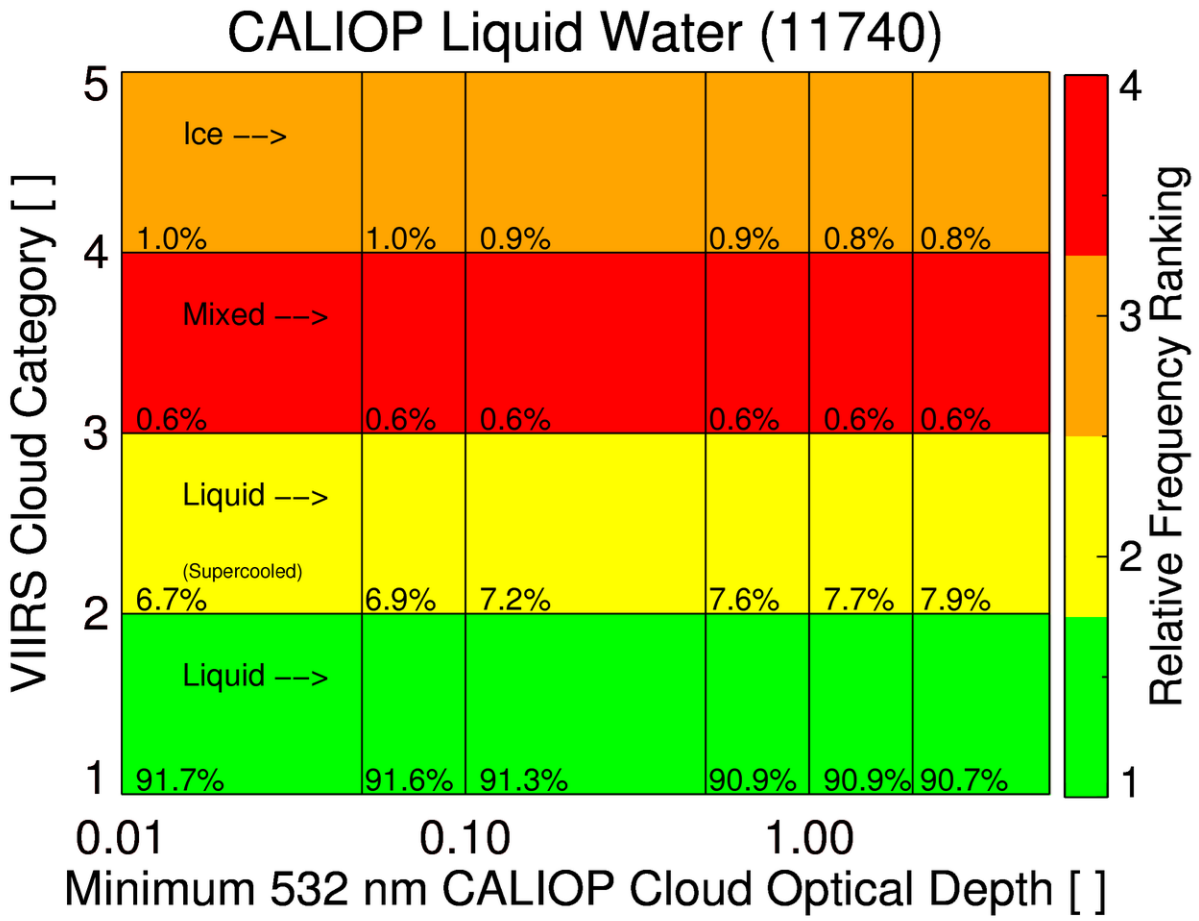


CALIOP vs. NOAA-20: Cloud Type

When clouds with an optical depth of 0.10 (common definition of detectable clouds for passive measurements) or greater are considered, the NOAA-20 cloud type product meets the accuracy specification. Identification of very thin cirrus that overlap lower cloud layers remains a challenge.



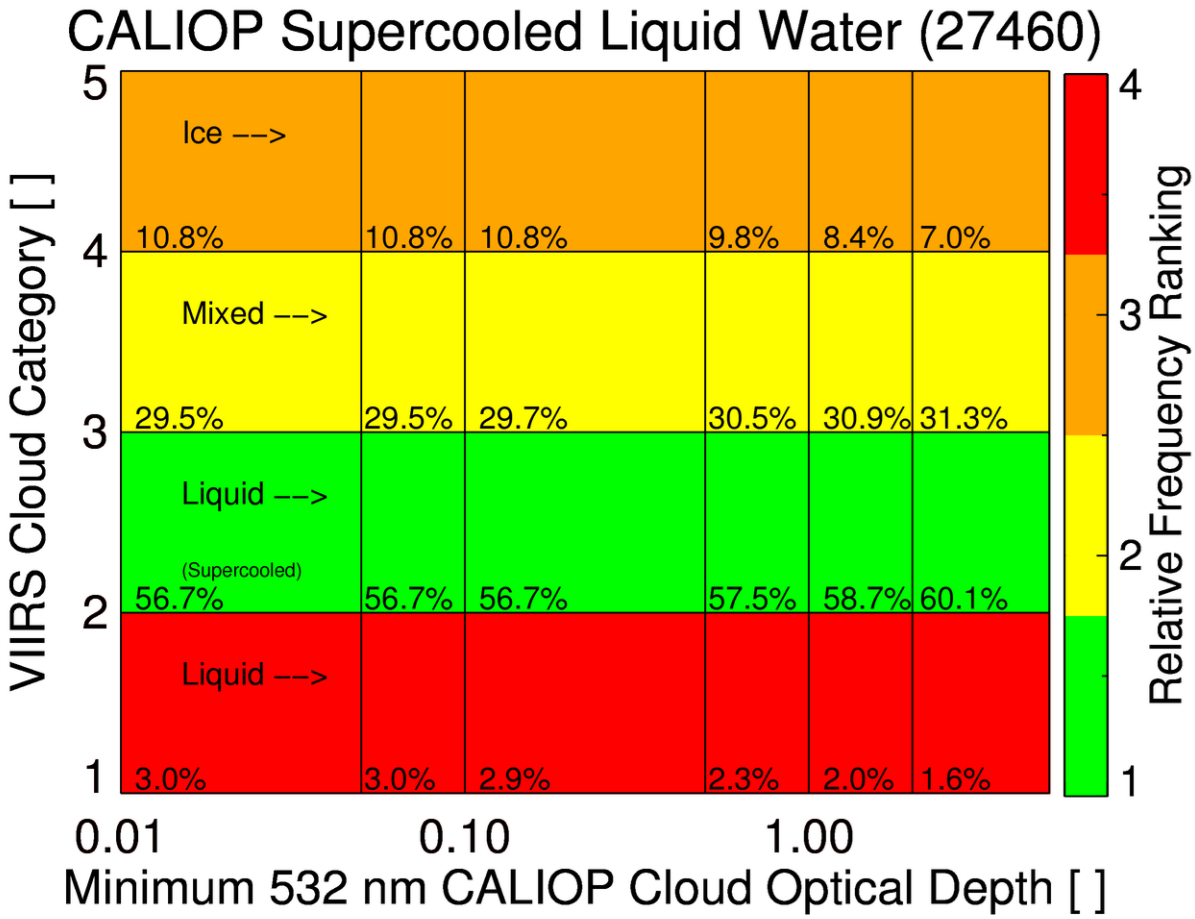
CALIOP vs. NOAA-20: Liquid Phase Assessment



When CALIOP indicates that liquid water clouds are present:

- **The VIIRS EDR agrees >90% of the time**
- **The second most common VIIRS EDR classification is supercooled liquid water (~7%)**

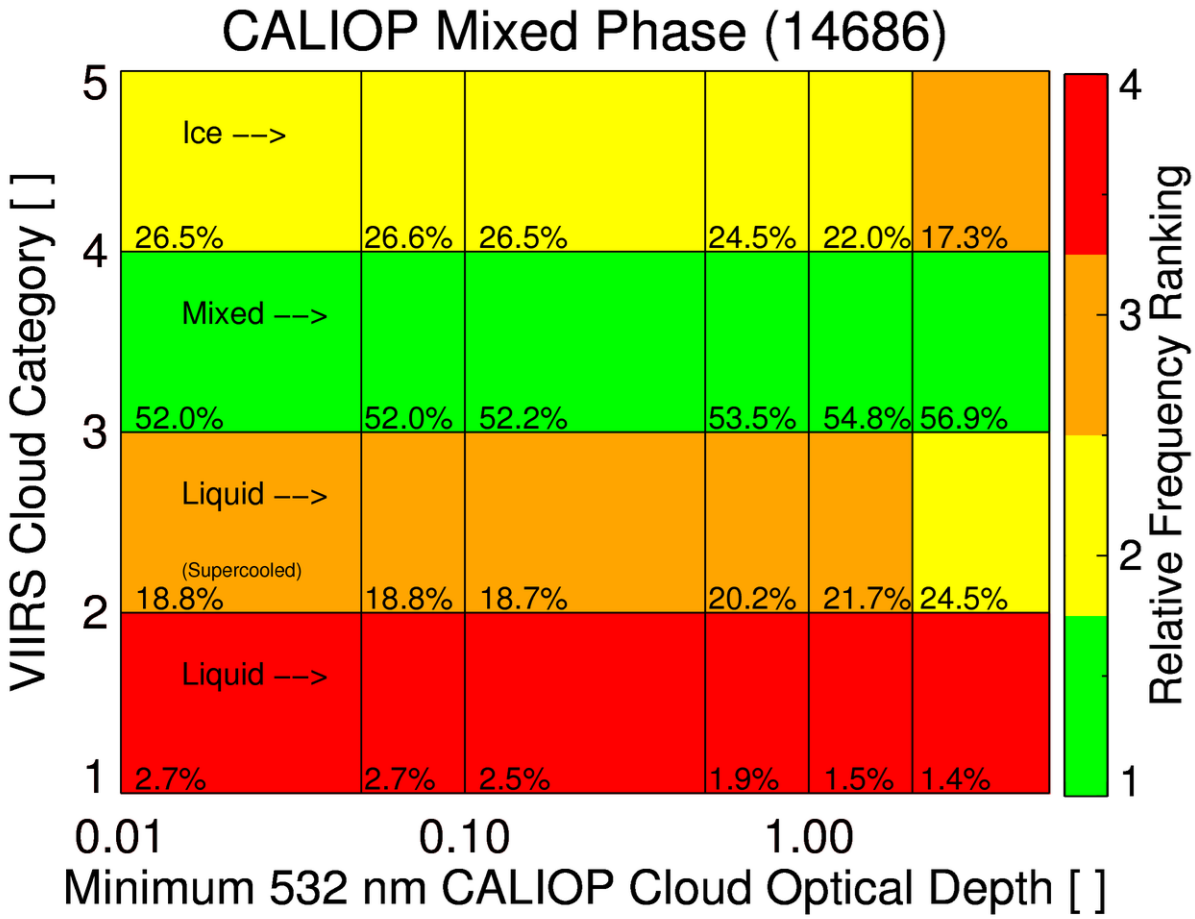
CALIOP vs. NOAA-20: Supercooled Liquid Water Assessment



When CALIOP indicates that supercooled liquid water clouds are present:

- **The VIIRS EDR agrees ~57% of the time**
- **The second most common VIIRS EDR classification is mixed phase (~30%)**
- **Ice phase misclassification is also fairly common (~11%)**

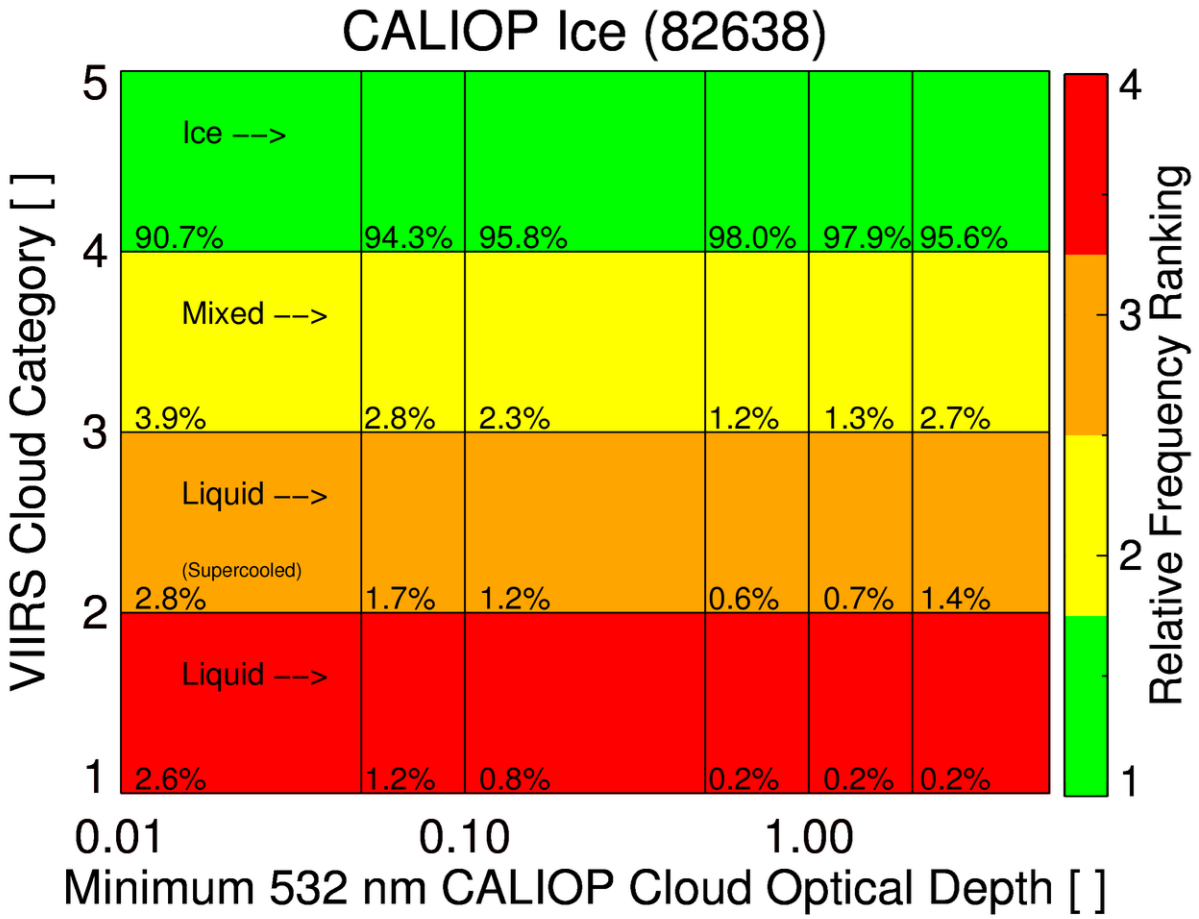
CALIOP vs. NOAA-20: Mixed Phase Assessment



When CALIOP indicates that mixed phase clouds are present:

- **The VIIRS EDR agrees ~52% of the time**
- **The second most common VIIRS EDR classification is ice phase (~27%)**
- **Supercooled liquid water misclassification is also fairly common (~19%)**

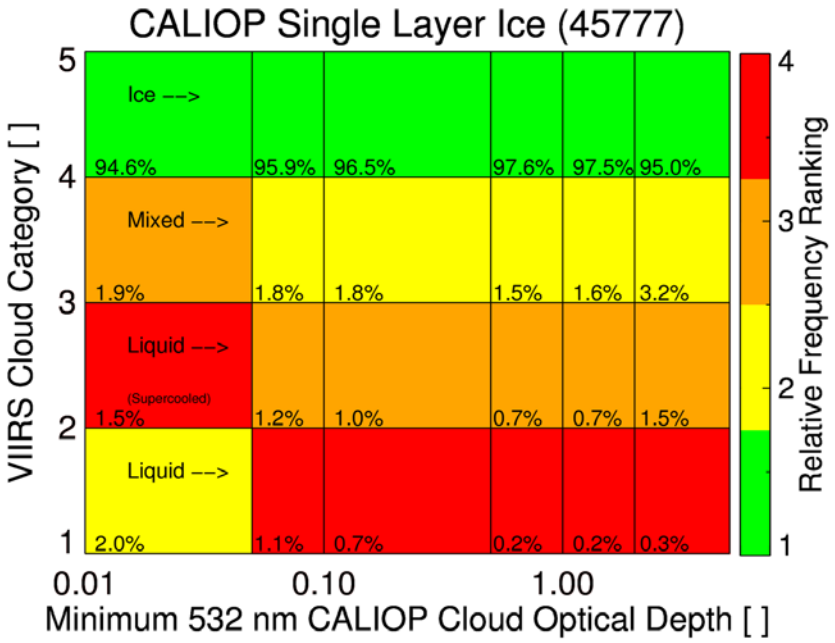
CALIOP vs. NOAA-20: Ice Phase Assessment

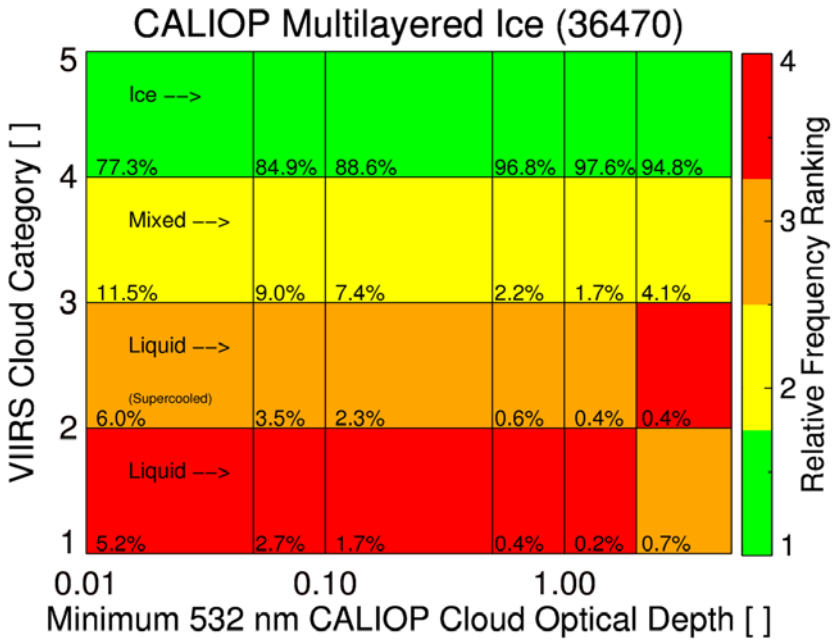


When CALIOP indicates that ice clouds are present:

- **The VIIRS EDR agrees >90% of the time**
- **The second most common VIIRS EDR classification is mixed phase (~4%)**
- **Supercooled liquid water misclassification occurs about 3% of the time**

CALIOP vs. NOAA-20: Single/Multilayered Ice



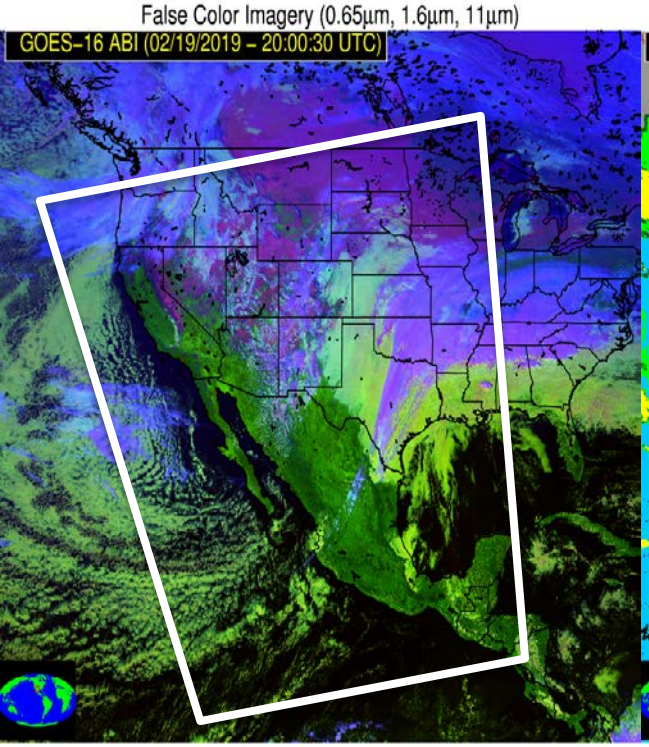


As expected, the presence of underlying cloud layers decreases the accuracy of the enterprise cloud phase algorithm (IR absorption channels would help!)

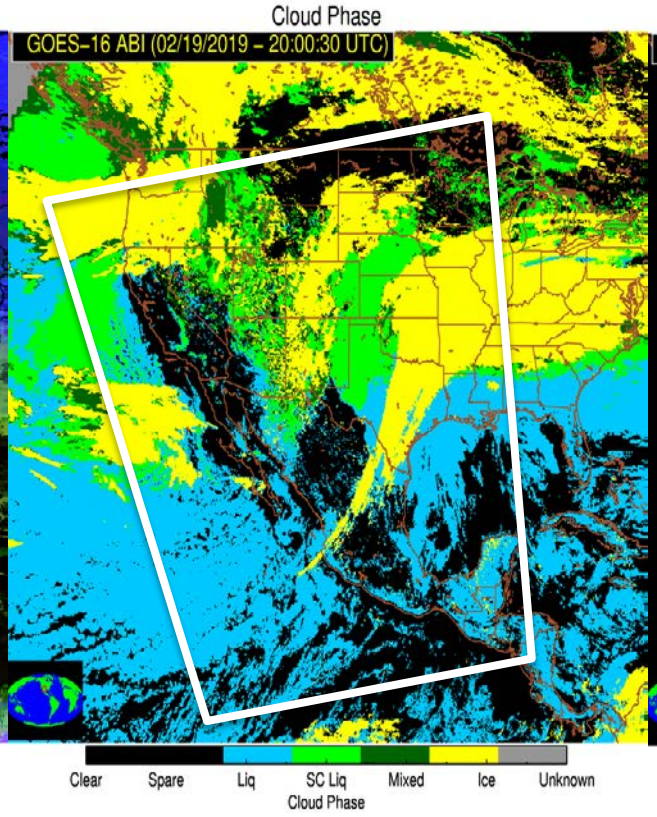
COMPARISON TO GOES-16

NOAA-20 vs. GOES-16: Daytime

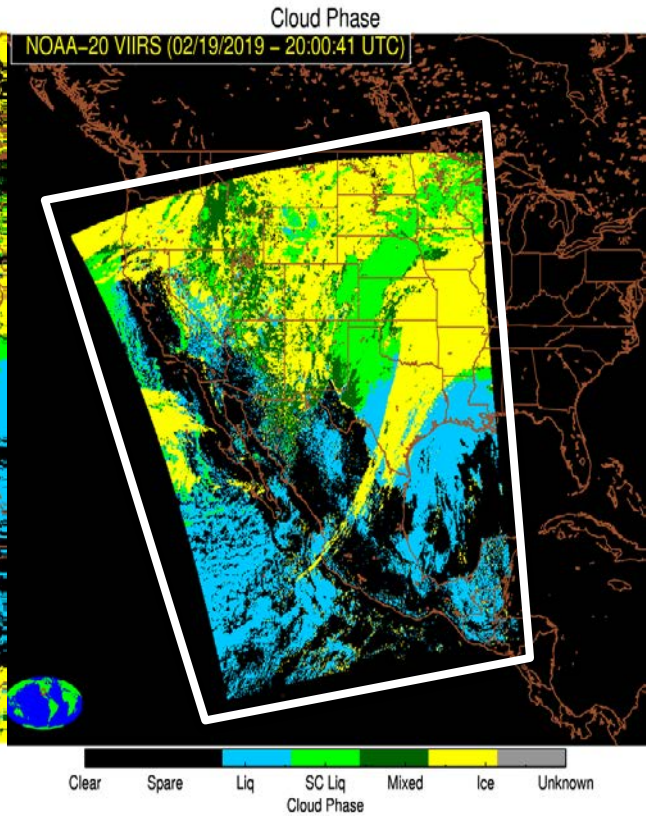
GOES-16 False Color



GOES-16 Cloud Phase



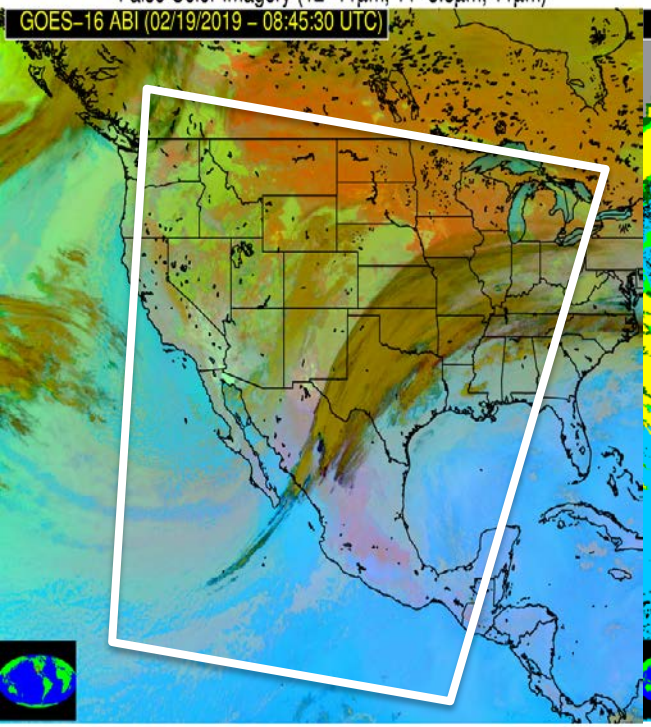
VIIRS EDR Cloud Phase



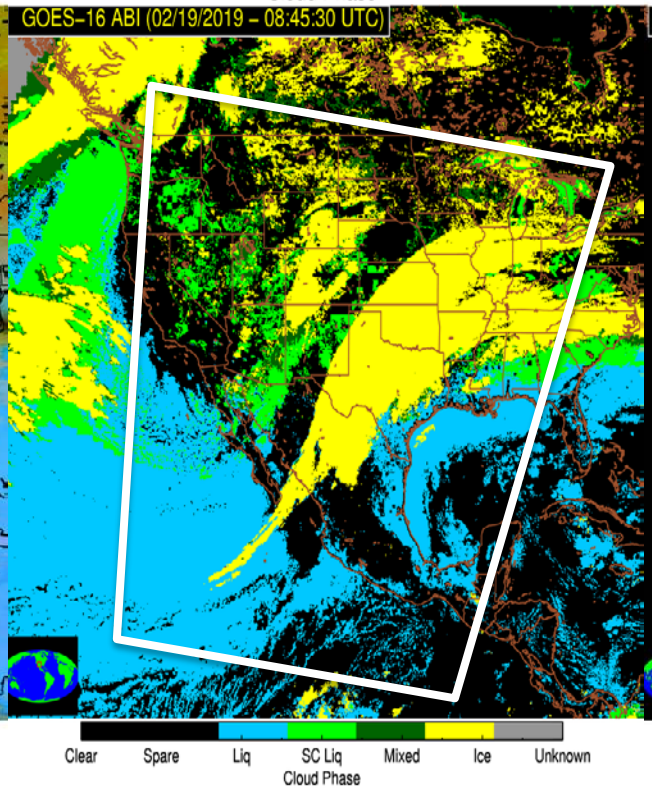
Where clouds are identifiable in the false color imagery, differences are mainly associated with mixed phase and supercooled categories

NOAA-20 vs. GOES-16: Nighttime

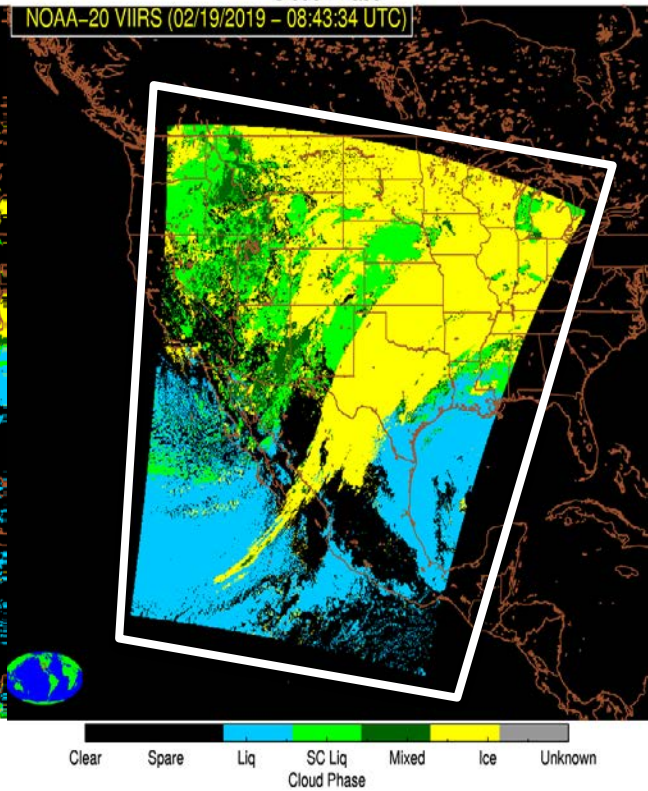
GOES-16 False Color



GOES-16 Cloud Phase



VIIRS EDR Cloud Phase



Where clouds are identifiable in the false color imagery, differences are mainly associated with mixed phase and supercooled categories

NOAA-20 vs. GOES-16

- **The NOAA-20 cloud phase product was co-located with the GOES-16 phase on February 19, 2019**
- **Co-location criteria: VIIRS and ABI cloud masks both indicate a cloud is present and the ABI viewing angle was less than 60º**

Cloud Phase Confusion Matrix				
GOES-16 Ice	6,999,942	2,404,512	8,605,248	81,659,406
GOES-16 Mixed	538,087	1,407,953	3,280,619	1,597,349
GOES-16 SC	1,718,260	9,550,013	3,694,293	1,735,457
GOES-16 Liquid	70,967,424	2,485,909	1,619,085	8,529,582
Total: 206,793,136	NOAA-20 Liquid	NOAA-20 SC	NOAA-20 Mixed	NOAA-20 Ice

Percentage of NOAA-20 results that match GOES-16: 80.01%

S-NPP vs. GOES-16

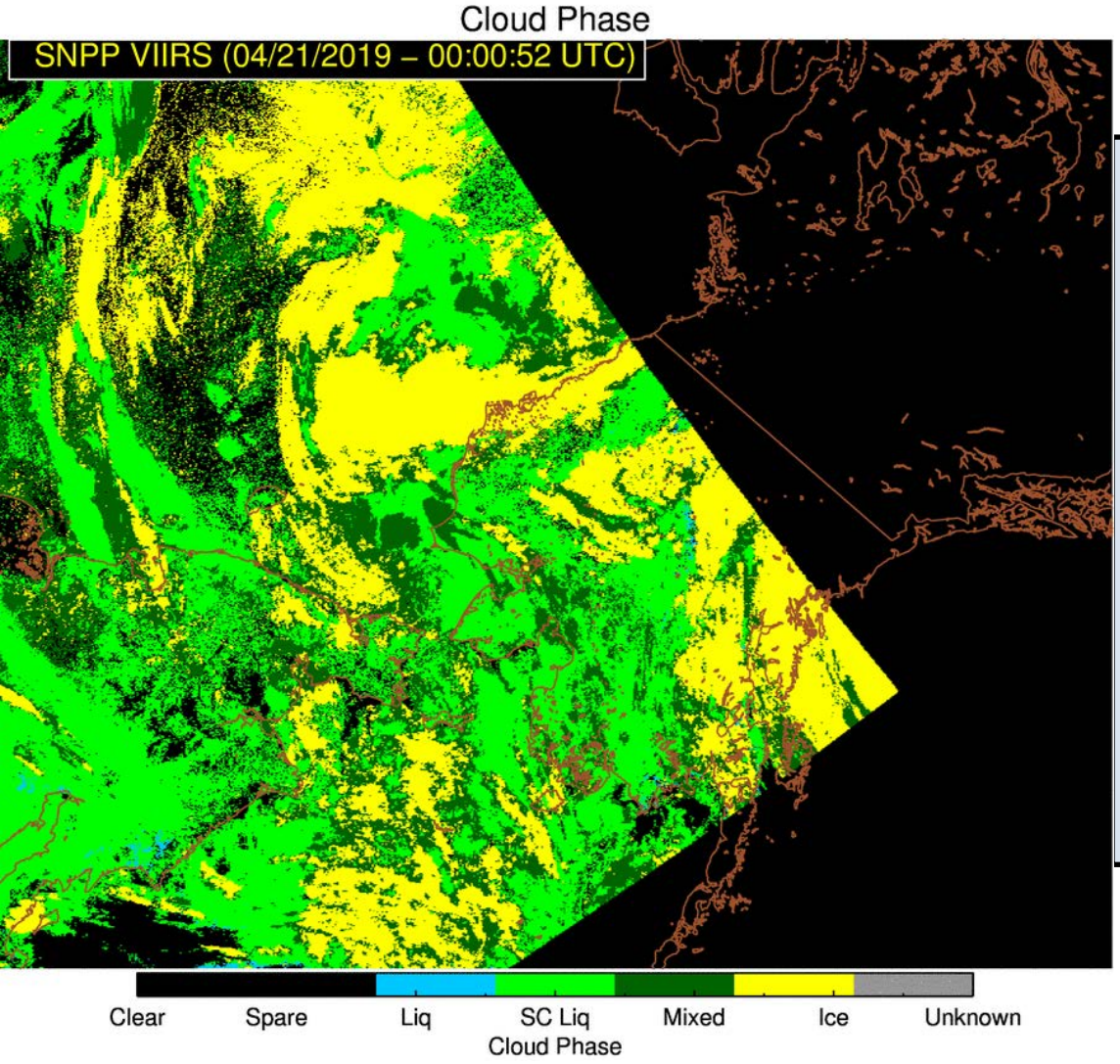
- **The S-NPP cloud phase product was co-located with the GOES-16 phase on February 19, 2019**
- **Co-location criteria: VIIRS and ABI cloud masks both indicate a cloud is present and the ABI viewing angle was less than 60º**

Cloud Phase Confusion Matrix				
GOES-16 Ice	9,883,109	4,100,852	10,011,274	80,619,600
GOES-16 Mixed	750,350	2,341,299	2,891,375	982,551
GOES-16 SC	2,002,496	12,861,596	1,766,657	753,263
GOES-16 Liquid	71,590,734	2,868,957	918,596	4,954,418
Total: 206,793,136	S-NPP Liquid	S-NPP SC	S-NPP Mixed	S-NPP Ice

Percentage of S-NPP results that match GOES-16: 80.25%

S-NPP AND NOAA-20 CONTINUITY

S-NPP + NOAA-20 Cloud Phase EDR



- Animation composed of sequential cloud phase images from NOAA-20 and S-NPP for April 21, 2019
- When visualized in time sequence, the S-NPP and NOAA-20 VIIRS cloud phase EDR generally exhibits good spatial and temporal continuity
- Most variability is associated with mixed phase (the most difficult category)

Evaluation of Required Algorithm Inputs

- **Primary sensor data:** VIIRS M14, M15, and M16
  - No issues
  - Performance is consistent with S-NPP (no threshold changes were needed)

- **Derived sensor data:** VIIRS enterprise cloud mask
  - The VIIRS cloud mask detects most clouds scene in multi-spectral imagery, which allows for a complete evaluation of the cloud phase EDR
  - Clear sky applications should dictate any cloud mask tweaks

- **Ancillary data:** GFS fields drive the required clear sky radiative transfer model
  - The FV3 was evaluated and ~97% of the FV3 results were identical to the legacy GFS
  - The transition to FV3 should not be an issue

Error Budget

Attribute Analyzed	JERD Threshold	Pre-Launch Performance	On-orbit Performance	Meet Requirement?	Additional Comments
Cloud Phase: Accuracy	80%	80%	80% when 532 nm cloud optical depth > 0.05	Yes	Poorest performance: potentially mixed phase clouds
Cloud Type: Accuracy	60%	60%	60% when 532 nm cloud optical depth > 0.05	Yes	Poorest performance: potentially mixed phase clouds

Additional spectral measurements are needed to further improve the performance (e.g. M5, M9, M10, M12) (CrIS would help as well)

User Feedback

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

None so far

Downstream Product Feedback

Primary cloud phase issues that impact all algorithms dependent on cloud phase:

1. The edge of liquid water clouds is sometimes misclassified as ice
2. The cloud phase EDR is sometimes inconsistent with SWIR derived phase information when potentially mixed phase clouds are present
3. Thin cirrus may be missed when underlying cloud layers are present

Algorithm	Product	Downstream Product Feedback - Reports from downstream product teams on the dependencies and impacts
Enterprise Cloud Height (ACHA)	cloud height/temperature/pressure	Cloud phase issues #1 and #2 often cause the cloud height to be biased high. Issue #3 will often cause the cloud height to be biased low.
DCOMP	cloud optical depth and effective radius	The wrong optical property LUT may be used if the phase classification is incorrect.
NCOMP	cloud optical depth and effective radius	The wrong optical property LUT may be used if the phase classification is incorrect.

Risks, Actions, and Mitigations

Identified Risk	Description	Impact	Action/Mitigation and Schedule
Missing Granules	Numerous missing granules limited validation opportunities	None	Closed: This issue was fixed, leaving sufficient time to perform the full validation analyses
Situational Performance	Cloud edges, potentially mixed phase clouds, and multilayered clouds are challenging, especially without infrared absorption channels	Low (does not prevent spec from being met)	Ongoing challenge: Additional spectral measurements from VIIRS, and possibly CrIS, are needed. Such updates would require a significant effort (resources would need to be evaluated).

Documentation

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes
System Maintenance Manual (for ESPC products)	Unknown
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes for theoretical basis (Pavolonis, 2010)
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	As requested

Check List - Validated Maturity

Validated Maturity End State	Assessment
Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).	Yes
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.	Yes
Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.	Yes
Product is ready for operational use based on documented validation findings and user feedback.	Yes
Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument	Yes

Conclusion

- Cal/Val results summary:
  - Team recommends algorithm validated maturity
    - Comparisons to space-based lidar indicate that the NOAA-20 VIIRS cloud phase and cloud type EDRs meet the accuracy requirements documented in the JERD
    - Algorithm performance in certain situations can be improved through incorporation of additional spectral measurements

Path Forward

- Consistent with the S-NPP cal/val effort, the classification of potentially mixed phase clouds, cloud edges, and certain multilayered cloud systems remain a challenge
- The cloud phase EDR can be improved through incorporation of additional VIIRS spectral channels (e.g. M5, M9, M10, M12)
- Incorporation of CrIS measurements would also help
- The incorporation of additional spectral information requires significant effort, so compelling justification and a reevaluation of resources is needed to proceed
- We will continue to assess the performance of the NOAA-20 cloud phase and type EDRs through comparisons to independent measures of cloud phase/type, such as space-based lidar