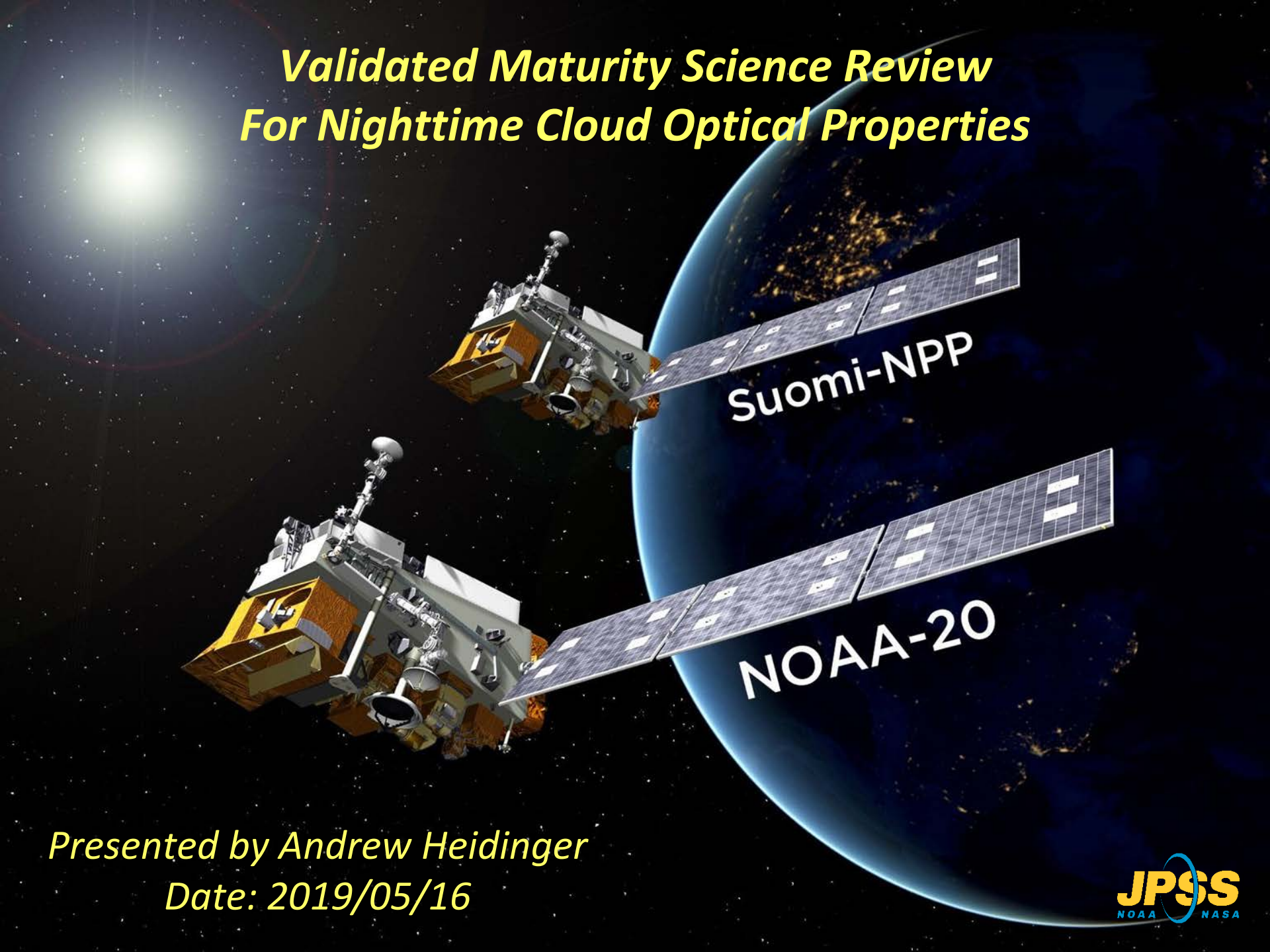
Validated Maturity Science Review For Nighttime Cloud Optical Properties



Presented by Andrew Heidinger

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 MATERIAL

NCOMP Cal/Val Team

Algorithm Cal/Val Team Members

Name	Organization	Major Task
Patrick Minnis	NASA LaRC/SSAI	Team Lead
Patrick Heck	UW SSEC/CIMSS	Algorithm development and maintenance
Chris Yost	SSAI	Validation lead
William Straka	UW SSEC/CIMSS	ASSISTT Liaison
David Donahue	OSPO	Cloud Algorithm PAL
Shuang Qiu	OSPO	PAL

Product Overview

- NCOMP is the Nighttime Cloud Optical and Microphysical Properties algorithm.
- NCOMP was developed for GOES-AWG and works presently on VIIRS-SNPP and VIIRS-NOAA-20. It was based on NASA Langley's Solar-infrared Infrared Split-window Technique (SIST) that applied to nighttime data for GOES, GOES-ABI, Himawari-ABI, MSG-SEVIRI, AQUA-MODIS, Terra-MODIS, and other instruments.
- NCOMP is a FORTRAN 90/95 package which works with the identical code for both VIIRS and GOES.

- **NCOMP** uses the following **input**, in addition to the radiances from VIIRS three channels.
  - –Cloud type
  - –Cloud top temperature
  - –Surface type, surface emissivities (all 3 channels)
  - –Clear-sky IR RTM calculations
  - –All-sky temperature, atmospheric profiles, and skin temperatures (NWP)
  - –Cloud emittance parameterization coefficients (LUTs)

Product Requirements

Attribute	Threshold	Observed/validated
Geographic coverage	global	global
Vertical Coverage	n/a	n/a
Vertical Cell Size	n/a	n/a
Horizontal Cell Size	0.8 km	n/a
Mapping Uncertainty	4 km	n/a
Measurement Range	1-5 (COD) 2-32µm (Water Cloud CPS) 2-50µm (Ice Cloud CPS) 25-100g/m2 (LWP) 25-175g/m2 (IWP)	Same
Measurement Accuracy	30% (COD) 4µm or 30% (Water Cloud CPS) 10µm (Ice Cloud CPS) 25g/m2 or 15% (LWP) 25g/m2 or 30% (IWP)	9.8% (Ice Cloud COD) N/A N/A -9.3g/m2 or 23.2% (LWP) -6.2g/m2 or 28.9% (IWP)
Measurement Precision	0.8 or 30% (COD) 4µm or 25% (Water Cloud CPS) 10µm or 25% (Ice Cloud CPS) 25g/m2 or 40% (LWP) 25g/m2 or 40% (IWP)	1.0 or 20.4% (Ice Cloud COD) N/A N/A 28.7g/m2 or 71.6% (LWP) -6.2g/m2 or 104.6% (IWP)
Measurement Uncertainty	Not specified	Not specified

Processing Environment and Algorithms

- NCOMP currently being processed within SAPF at NDE:
  - Operational Code base **v2r0** (February 2018 Science code delivery).
  - Current code (**v2r0**) running in NDE Operational String since March 2019 for NOAA-20
  - CCL will be split into a seperate output file as soon as NDE-specified metadata is defined (likely v2r2)

Evaluation of algorithm performance to specification requirements

- Findings/Issues from Provisional Review
  - NCOMP meets accuracy specs for single-layer ice clouds with $\tau > 1$.
  - Similarly, NCOMP meets or is close to meeting precision specs.
  - Comparison to CALIOP and AMSR2 retrievals demonstrate good product performance. All products that have validation sources, albeit indirect, meet accuracy requirements and are very close to meeting precision.

- Improvements since Provisional Review
  - Validation datasets were improved, including using an updated CALIOP data product.
  - Twilight times were removed from the comparisons since NCOMP is required to meet specifications only at night.

Algorithm performance evaluation

Unlike other cloud products, e.g., cloud height, cloud fraction, cloud phase, NCOMP products are radiative parameters. Thus, it is not possible to validate optical thickness and effective radius directly from in-situ observations without making assumptions about the scattering properties of cloud particles. Therefore bona fide independent validation sources do not exist.

Our Specific Evaluation Methodology applied here:

- Visual checks of product imagery
- Direct comparison with CALIPSO products for ice cloud COD.
- For ice clouds we also use LIDAR retrievals to validate cloud Ice Water Path. IWP is directly computed from COD and CPS. Validation of IWP is therefore an indirect validation of COD and CPS.
- Similarly, for liquid clouds we use passive microwave retrievals to validate Liquid Water Path. LWP is directly computed from COD and CPS. Validation of LWP is therefore an indirect validation of COD and CPS.

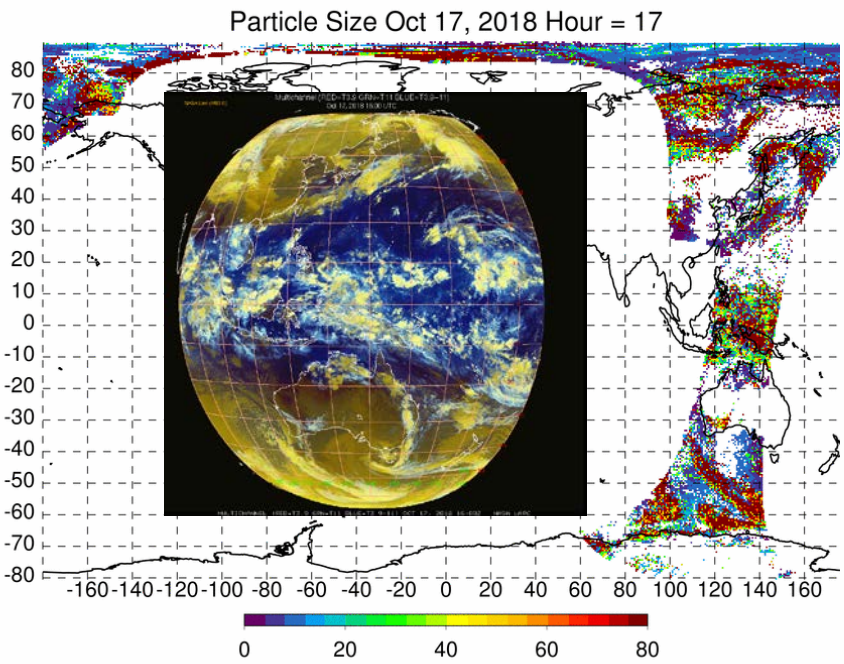
Data Used in this Analysis

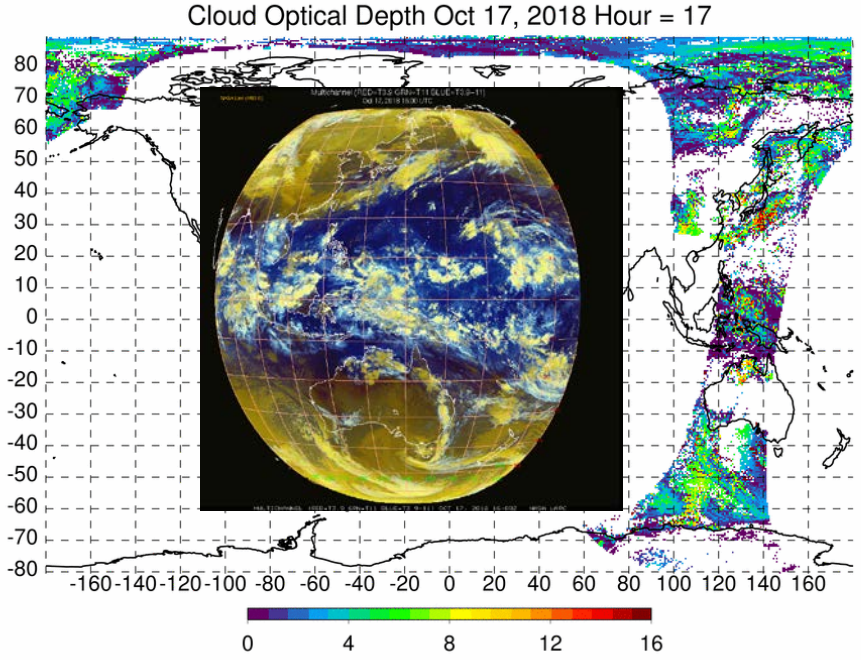
- NOAA-20: 40 days from September to December, 2018
- NOAA-20: 7 days from February, 2019
- SNPP: 7 days from February, 2019
- CALIOP/CALIPSO: 40 days from September to December, 2018
- AMSR2/GCOM-W: 40 days from September to December, 2018

NCOMP Products

One Hour of NCOMP JPSS VIIRS Granules with Himawari-8 Imagery

Oct. 17, 2018 1700-1759 UTC



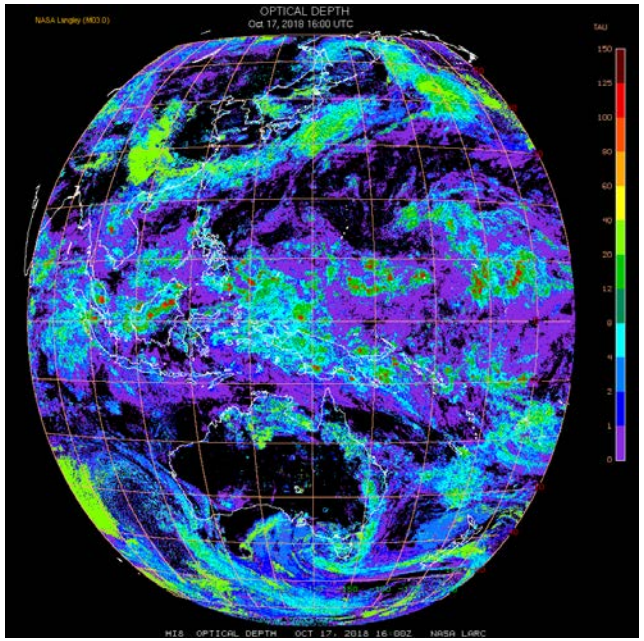


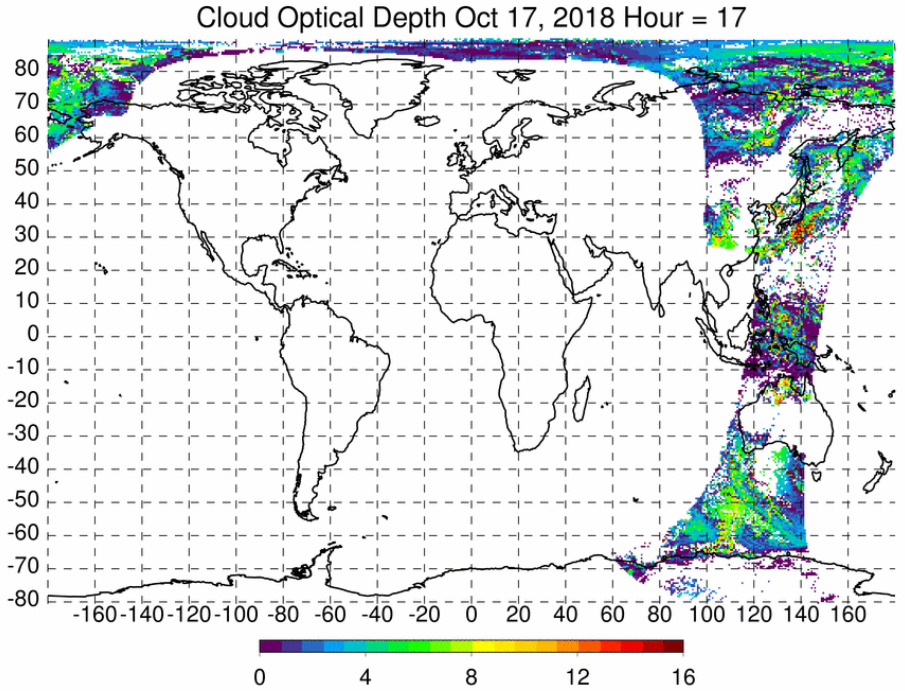
CPS and COD look reasonable off southern Australia, into the tropics, and northward

NCOMP Products

One Hour of JPSS VIIRS Granules with Himawari-8 SIST Products from NASA Langley

Cloud Optical Depth Oct. 17, 2018 1700-1759 UTC





NCOMP COD is similar to SIST COD despite algorithm differences (note different color scales)

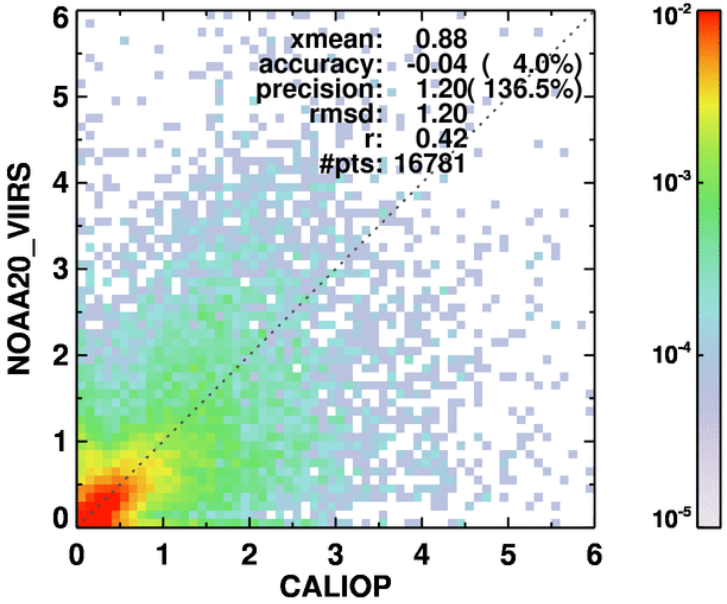
Validation of Cloud Optical Depth with CALIOP

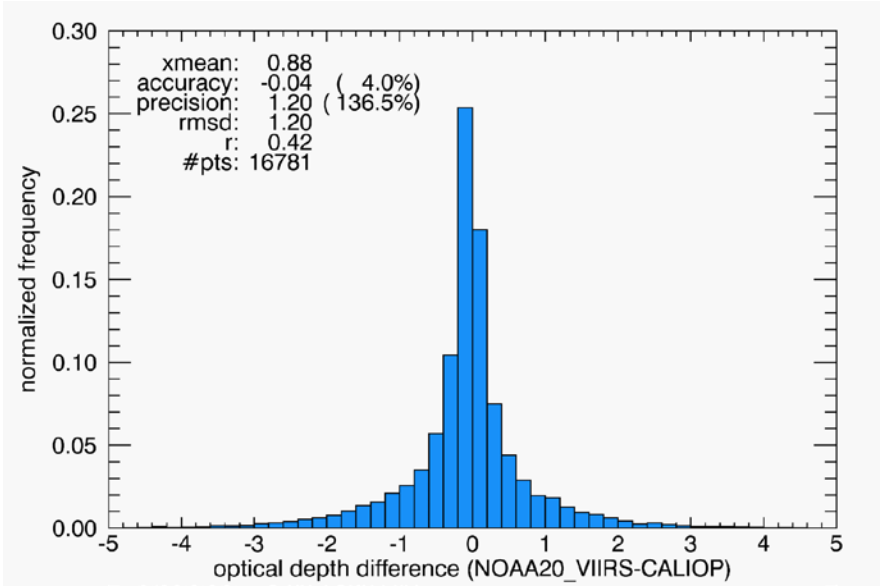
CALIOP Comparison

NCOMP COD Compared to CALIOP COD for Ice Clouds

VIIRS: 40 Days of Granules

CALIOP: Constrained + Unconstrained





Measurement Accuracy	30%
Measurement Precision	Greater of 8.0 or 30%

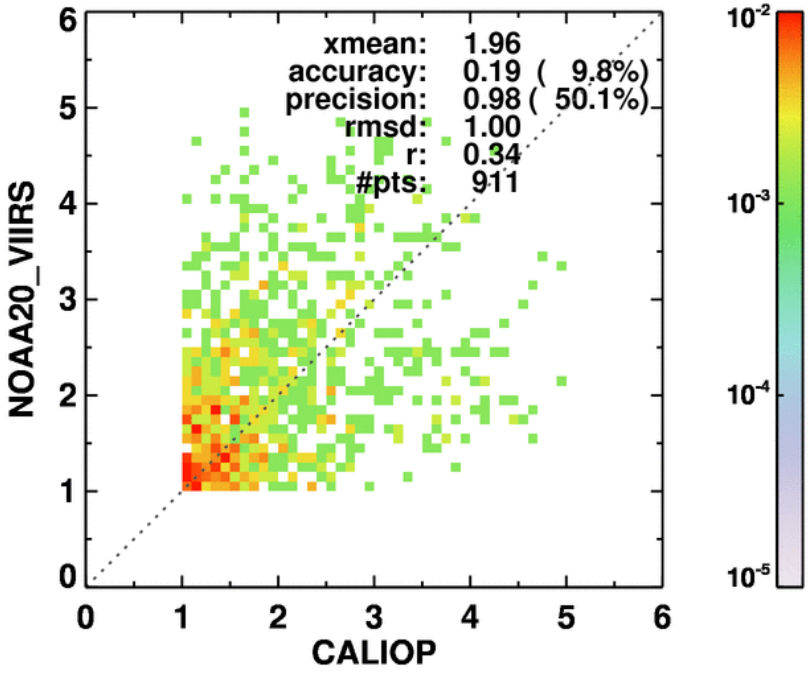
- NCOMP COD accuracy is excellent, but scatter is large so precision specification is not yet met.
- Many points outside NCOMP COD range of 1.0 ≤ COD ≤ 5.0, particularly at the low end.

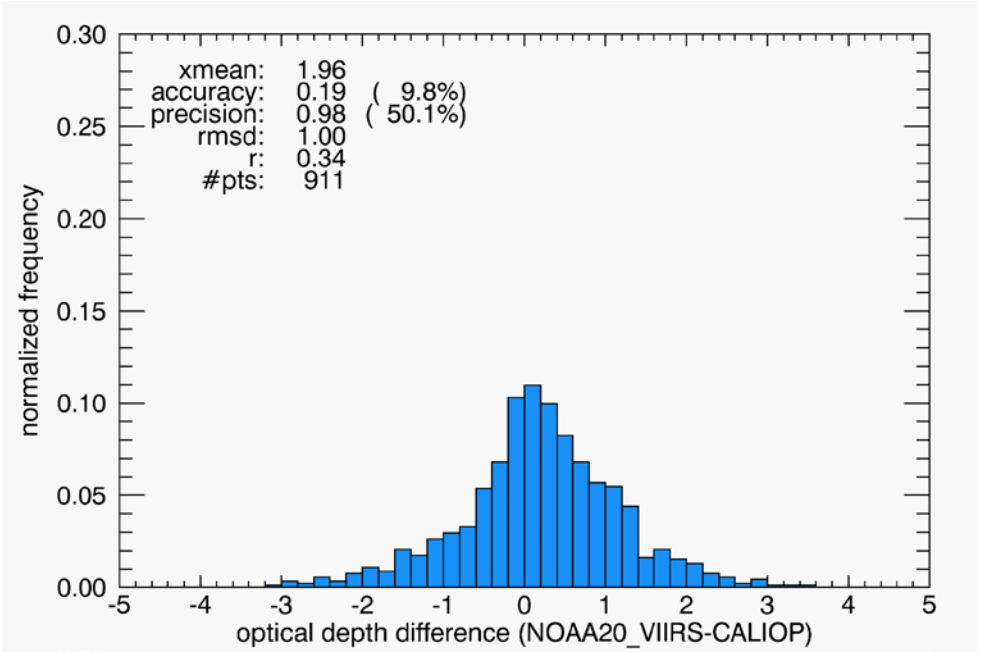
CALIOP Comparison

NCOMP COD Compared to CALIOP COD for Ice Clouds

VIIRS: 40 Days of Granules

CALIOP: Constrained Only, no horizontal feature filter





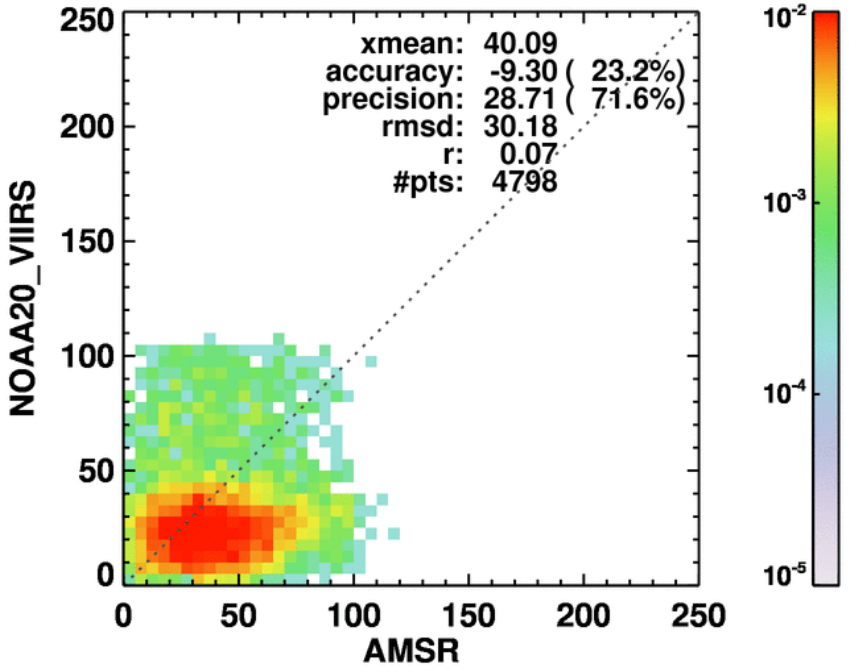
Measurement Accuracy	30%
Measurement Precision	Greater of 8.0 or 30%

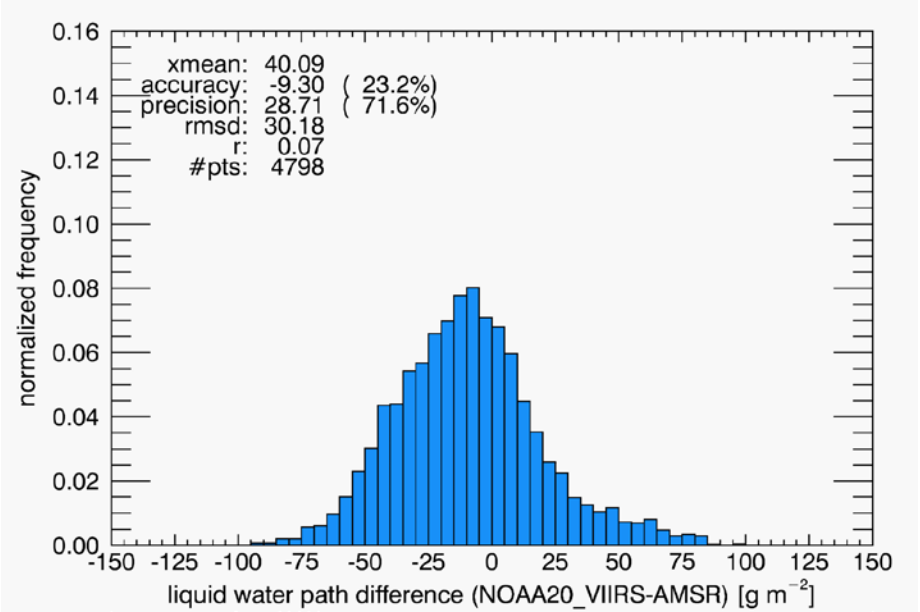
- NCOMP COD remains accurate, scatter improves despite relaxation of CALIOP horizontal cloud feature filter. Precision = 0.98

Validation of Liquid Water Path with ASMR2

AMSR2 Comparison

Filters
- NCOMP COD restricted to 1 – 5
- LWP for both > 0
- Allow AMSR2 DQF to be “clear”





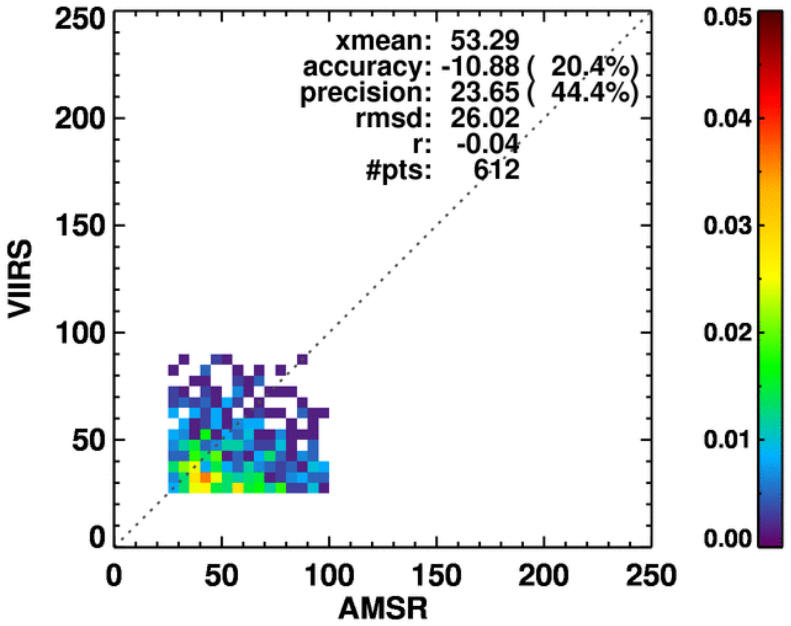
Measurement Accuracy	Greater of 25g/m^2 or 15%
Measurement Precision	Greater of 25g/m^2 or 40%

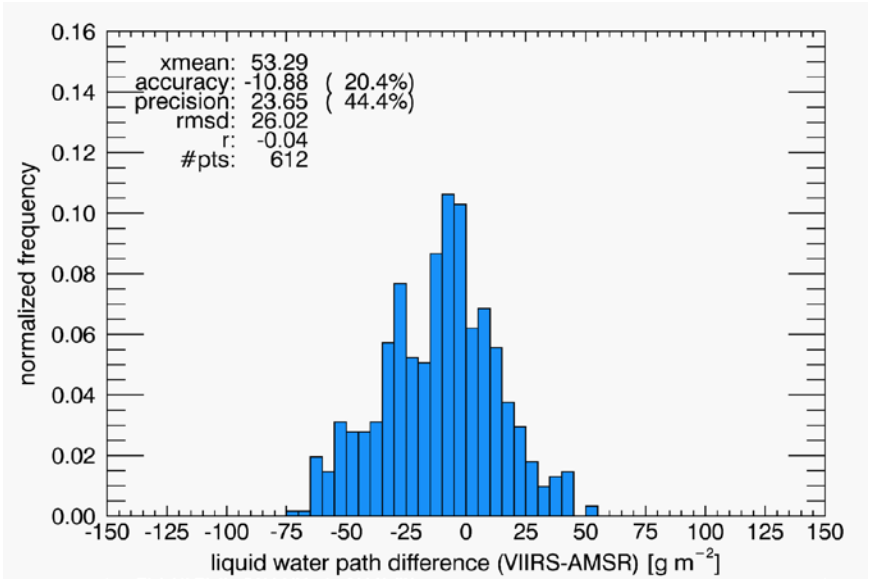
- Accuracy spec is mostly met, but scatter is large – not unexpected given AMSR2 COD sensitivity limitation

AMSR2 Comparison

Additional Filters:

- LWP limited to NCOMP range
- Restrict AMSR2 to CALIOP Horizontal Cloud Feature > 15km
- NCOMP COD restricted to 1 – 5
- LWP for both > 0





Measurement Accuracy	Greater of 25g/m^2 or 15%
Measurement Precision	Greater of 25g/m^2 or 40%

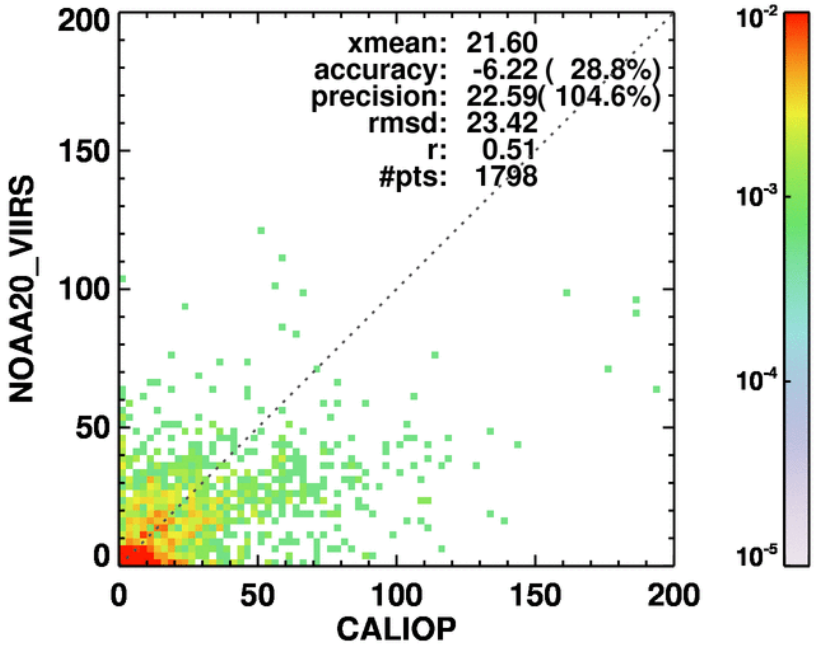
- Accuracy and precision performances improve and mostly met, but number of points greatly reduced.

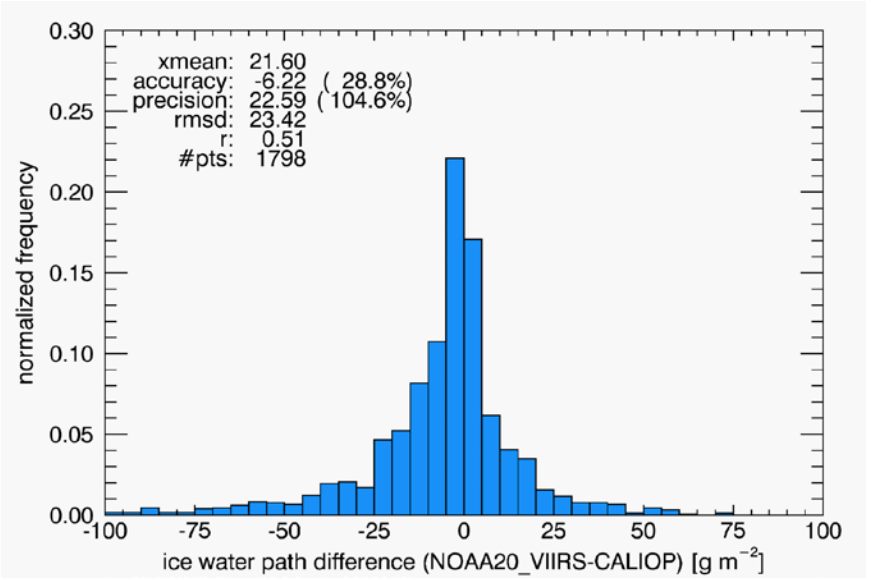
Validation of Ice Water Path with CALIOP

CALIOP IWP Comparison

NCOMP IWP Compared to CALIOP IWP

VIIRS: 40 Days of Granules CALIOP: Constrained, 25km horizontal feature





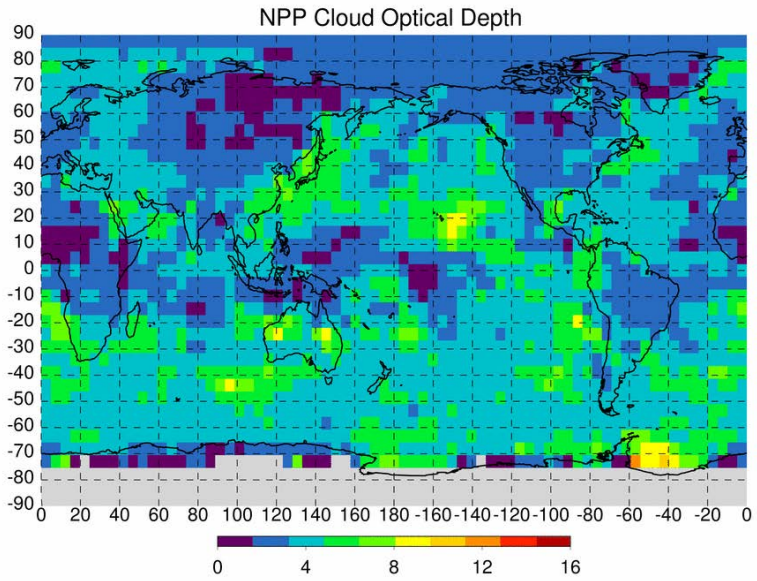
Measurement Accuracy	Greater of 25 g/m^2 or 30%
Measurement Precision	Greater of 25 g/m^2 or 40%

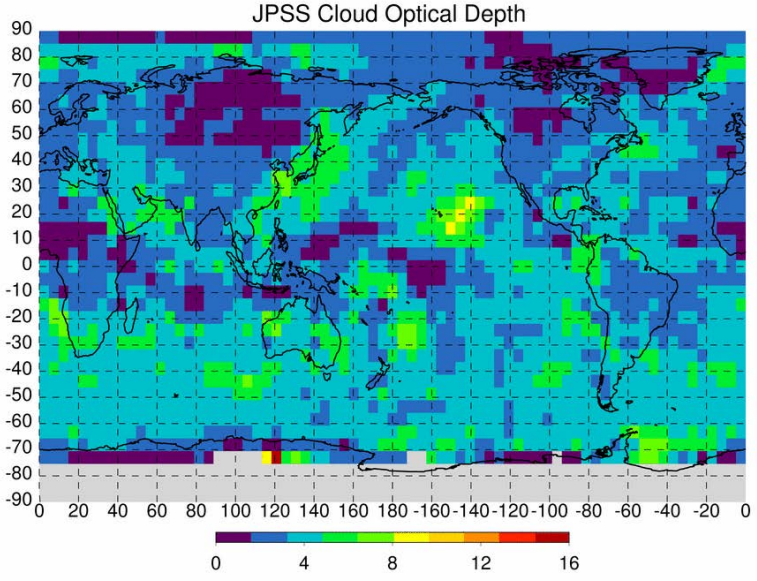
- NCOMP IWP meets accuracy specifications and precision specifications are close to being met. As with COD, CALIOP excels at thin ice clouds, so comparisons are difficult.

Comparisons with SNPP NCOMP

SNPP Comparison

Mean NCOMP COD for 1 Week of February 2019

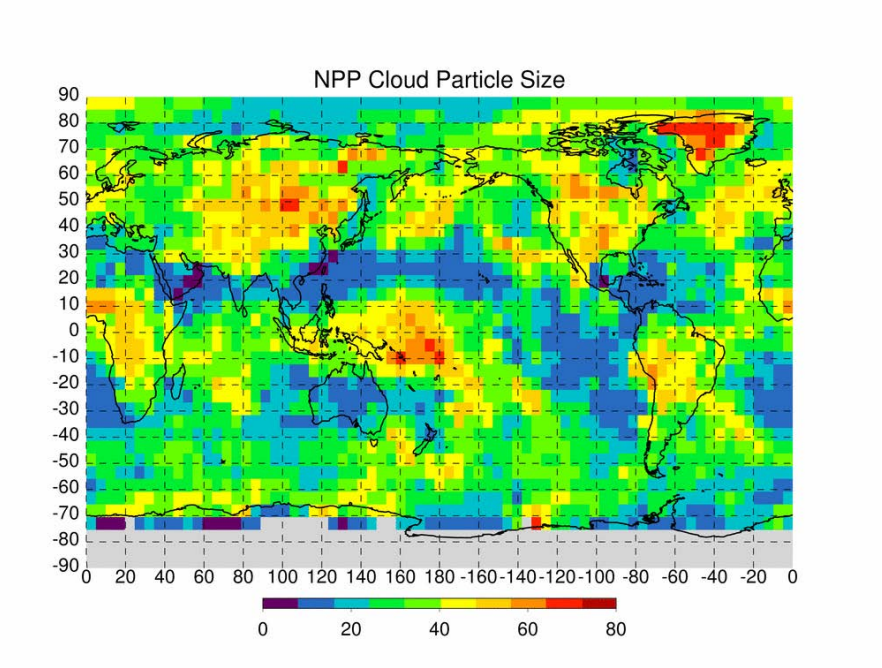


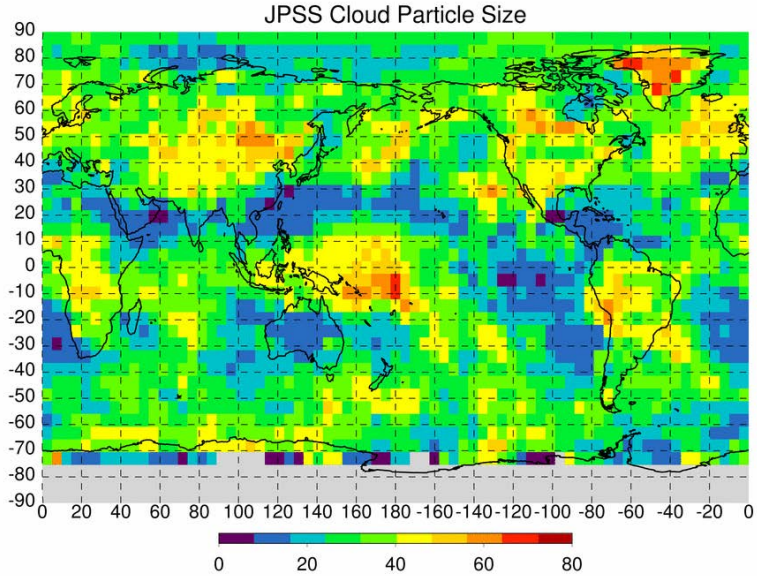


COD values and features across the globe look very similar.

SNPP Comparison

Mean NCOMP CPS for 1 Week of February 2019

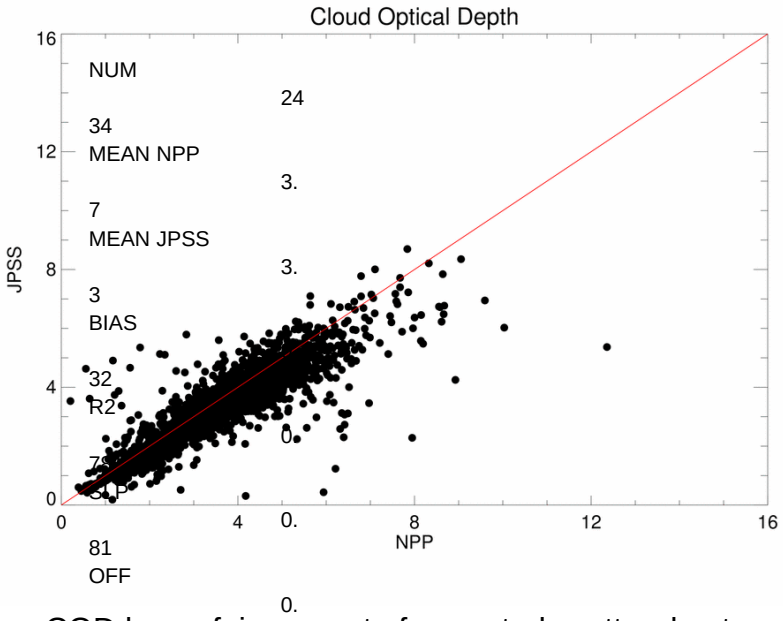




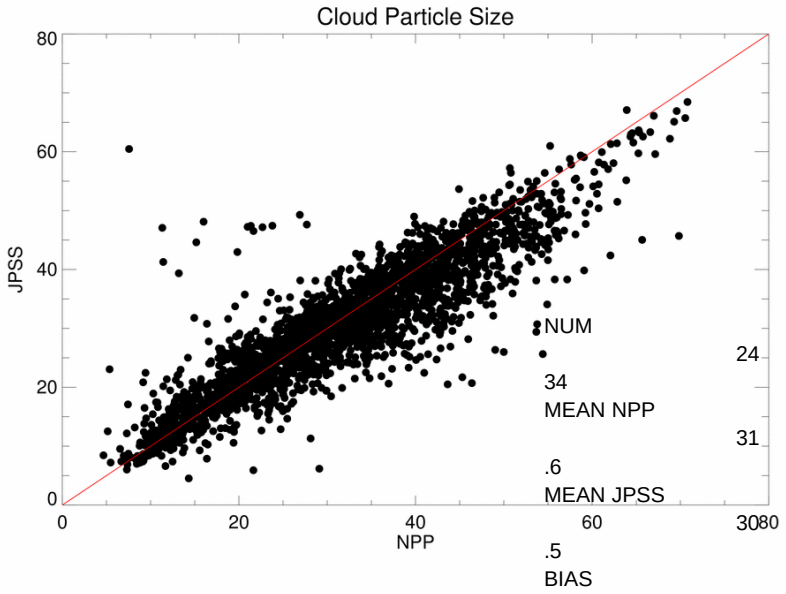
CPS values and features across the globe also look very similar.

SNPP Comparison

NCOMP COD and CPS from NPP and SNPP for 1 Week of Feb. 2019



COD has a fair amount of expected scatter due to sampling differences. The bias is likely due to calibration for one or both of the instruments.



CPS also has a fair amount of expected scatter. The small bias is also likely due to calibration for one or both of the instruments.

Validation- Summary

Product	Validation Source	Accuracy	Specs	Precision	Specs
COD Water	Indirect AMSR2	N/A	30%	N/A	0.8 or 30%
COD Ice	CALIOP	9.8%	30%	0.98 or 50.1%	0.8 or 30%
CPS Water	Indirect AMSR2	N/A	4µm or 30%	N/A	4µm or 25%
CPS Ice	Indirect CALIOP	N/A	10µm	N/A	10µm or 25%
LWP	AMSR2	-9.3 g/m^2 or 23.2%	25 g/m^2 or 15%	28.7 g/m^2 or 71.6%	25 g/m^2 or 40%
IWP	CALIOP	-9.3 g/m^2 or 23.2%	25 g/m^2 or 71.6%	23.2 g/m^2 or 71.6%	25 g/m^2 or 40%

Required algorithm inputs

- Required Algorithm Inputs
  - Upstream Algorithms
    - Cloud Mask
    - Cloud Type/Phase
    - Cloud Top Temperature
  - LUT
  - Primary Sensor Data
    - Calibrated Brightness Temperatures, radiances for M12, M15 and M16
    - Satellite zenith angle and viewing zenith angle
    - Space Mask
    - Bad pixel mask for M12, M15 and M16
  - Static and Dynamic Ancillary Data
    - Surface emissivity from SEEBOR, surface elevation and type
    - NWP profiles
    - Clear-sky Infrared RTM Calculations for M12, M15 and M16 (transmission and radiance profiles, clear sky brightness temperatures and radiances)
    - Blackbody radiance profiles for M12, M15 and M16

Evaluation of the effect of upstream cloud type algorithm

- Inaccuracies in the upstream Cloud Type/Phase and Cloud Top Temperature products does impact NCOMP cloud products.
- The cloud emittance parameterizations are a function of cloud phase, so the modeled TOA radiances within NCOMP will be inaccurate if the phase is incorrect.
- Similarly, the retrieval of COD and CPS are dependent on the Cloud Top Temperature. Small inaccuracies do not have a large impact.
- These impacts have not been rigorously quantified.

User Feedback

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

Downstream Product Feedback

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

Risks, Actions, and Mitigations

Identified Risk	Description	Impact	Action/Mitigation and Schedule
NDE processing	Missing granules in NDE processing	Moderate	Closed - Issue fixed with sufficient time for full validation analyses,

Documentations

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes (Provisional. Full Validation ReadMe will be provided after review)
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes
System Maintenance Manual (for ESPC products)	Yes
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	As requested. LTM of algorithm is performed regularly via Cloud Team website

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).	All requirements have been met
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

- Accuracy specs are met for ice cloud COD and precision specs are mostly met. For non-NDE products LWP and IWP, the same can be said.
- The only independent validation source of LWP is AMSR2 and it has met requirement specifications for other NCOMP applications NCOMP. LWP is computed from NCOMP COD and CPS, so a successful validation of LWP implies NCOMP COD and CPS for water clouds are reasonable.
- Similarly for IWP, CALIOP is the IWP validation source and has met all requirement specifications for other applications. IWP is computed from NCOMP COD and CPS, so a successful validation of IWP implies NCOMP COD and CPS for ice clouds are reasonable.
- JPSS COD and CPS are consistent with NPP results.
- We expect an improvement if we collect more validation days so that more spatial and temporal filtering can be done without impacting statistical significance. Removing twilight granules will also improve performance.
- **The Cloud Team recommends Full Maturity at this time.**

Path Forward

- Planned improvements
  - Analyze and mitigate any CPS retrieval high bias for ice clouds by evaluating the retrieval scheme and implementing any corrections. Comparisons with SIST will be used diagnostically.
  - A planned update to the IWP formulation should improve CALIOP comparisons. Similarly, new definitions of CPS for ice clouds will be implemented in NCOMP and are expected to also improve the IWP comparisons.
  - An extension of NCOMP's COD range for ice will be implemented in the algorithm. This will allow more robust comparisons with CALIOP IWP, which should increase specification performance and user applications.
  - Use new two-habit ice crystal models to compute improved cloud emittance parameterization.
  - Explore improving neural net approach for the extension of COD to apply to water clouds also. This would greatly expand and improve the ability to validate with AMSR2 thereby increasing inferred validation of water cloud COD and CPS.

- Future Cal/Val activities
  - We will continue routine long term monitoring via Cloud Team website to monitor for any anomalies which may occur

Backup Materials