Validated Maturity Science Review For NOAA-20 Enterprise Cloud Mask (ECM)

Presented by: Andrew Heidinger (STAR)

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

Algorithm Cal/Val Team Members

Name	Organization	Major Task
Andrew Heidinger	NOAA/NESDIS/STAR	Overall Lead, ECM Developer
Thomas Kopp	Aerospace Inc.	User and Program Interaction
Denis Botambekov	CIMSS	Performance Analysis
Jay Hoffman	CIMSS	Long-term Monitoring Website
William Straka	CIMSS/ASSISTT	ASSISTT Liaison, ECM Bridge Codes
David Donahue	OSPO	Cloud Algorithm PAL
Shuang Qiu	OSPO	Product Area Lead

Product Overview

- It is probabilistic, using machine learning (naive Bayesian formulation) and NASA CALIPSO data as its training.
- The primary output is the cloud probability (0 - 1 floating point number).
- The 4-Level cloud mask is derived solely from the cloud probability.
- ***We strongly encourage algorithm teams to derive their own threshold on the cloud probability for their own applications.***
- Enterprise mask is comprised of multiple classifiers (aka tests). A 4-level mask from each classifier is also available. It is packed into sets of bytes.
- The demand for one algorithm to serve many sensors drove the ECM development.

Product Requirements (JERD) and Observed CALIOP Validation

Attribute	Threshold	Observed/validated (CALIOP)
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	Cloudy / not cloudy	cloudy/not cloudy
Measurement Accuracy (Global, Ocean Day, Ocean Night, Land Day, Land Night, Desert Day, Desert Night, Snow Day, Snow Night, Sea-Ice Day, Sea-Ice Night, Antarctic Day, Antarctic Night)	87%, 92% 90%, 90%, 88%, 85%, 85%, 88%, 85%, 82%, 72%, 80%, 70%	88%, 94%, 92%, 91%, 90%, 89%, 88%, 89%, 85%, 83%, 75%, 80%, 72% (with COD < 0.4) (ALL ARE MET)
Missed Cloud (Leakage)	n/a	6%, 2%, 6%, 2%, 4%, 4%, 5%, 5%, 7%, 7%, 11%, 8%, 13%
False Cloud	n/a	6%, 4%, 2%, 7%, 6%, 7%, 7%, 6%, 8%, 10%, 14%, 12%, 15%

Note: COD filter is used to account for sensitivity difference between lidar and imager.

Product Requirements (JERD) and SST Difference Validation

Attribute	Threshold	Observed/validated (SST)
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	Cloudy / not cloudy	cloudy/not cloudy
Measurement Accuracy (Ocean Day, Ocean Night)	92% 90%,	92%, 90% (ALL ARE MET)
Missed Cloud (Leakage)	n/a	0%, 3%
False Cloud	n/a	6%, 4%

Note: COD filter is used to account for sensitivity difference between lidar and imager.

Required Algorithm Inputs

- Required Algorithm Inputs:
  - No upstream algorithms (*but a heavy use of ancillary data*)
  - LUT
    - Sensor dependent LUT
    - Prior mask based on MODIS
  - Primary Sensor Data:
    - Terrain corrected Geolocation
    - Calibrated Reflectances, Brightness Temperatures, Radiances
    - Satellite and solar zenith/azimuth angles

Required Algorithm Inputs

- Static and Dynamic Ancillary Data:
  - Surface type*
  - Surface elevation*
  - Land/Water mask*
  - Coast mask
  - Snow mask
  - Surface emissivity from UW-IREMIS*
  - GFS Forecasts
  - Viewing and solar Zenith and Azimuth Angles
  - Clear-sky Infrared RTM Calculations
  - MODIS Clear-sky TOA Reflectance*

* ***From the GOES-R AWG Project - Needs Updating.***

Processing Environment and Algorithms

- ECM currently being processed within SAPF at NDE:
  - Operational Code base **v2r0** (February 2018 Science code delivery).
  - Current LUTs:
    - These were updated since provisional (Nov 2018)
    - nb_cloud_mask_modis_prior_10312018.nc
      - md5sum: bc2fccb0a804b1b958f324ad307db5b5
    - viirs_default_nb_cloud_mask_lut_fw_10312018.nc
      - md5sum: 1ef0fe31cabdd00f9357ff06670b7938
  - Current code (**v2r0**) running in NDE Operational String since March 2019.

Algorithm Performance Evaluation

We have chosen independent sources of cloudiness that provide qualitative and quantitative analysis of the performance of 24 days distributed throughout 2018.

We also compare to non-NDE generation ECM data to diagnose NDE-specific issues.

Our Specific Validation Strategies are:

1. Visual inspection of NDE ECM against CLAVR-x ECM and IDPS VCM.
2. Comparison of Global Cloud Fraction from NDE to NASA MODIS MYD35.
3. Validation against NASA CALIPSO/CALIOP.
4. Analysis of SST biases.
5. Visual comparison to VCM and NASA VIIRS Mask

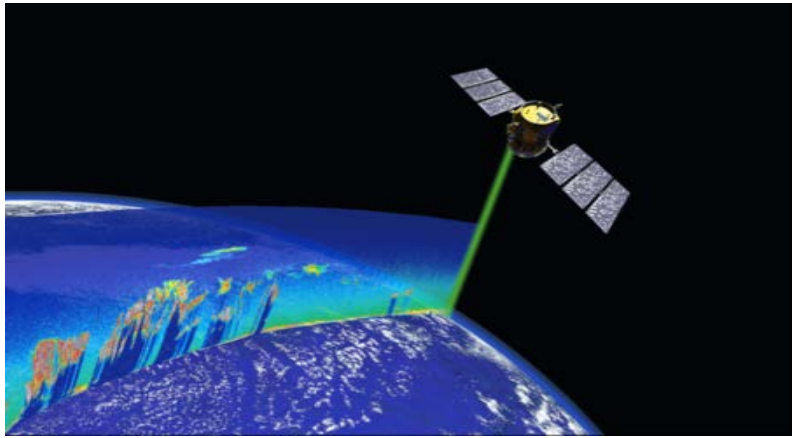
Details of Quantitative Assessment

Data Used in this Analysis

- NOAA-20 NDE v1r2 24 days (May 02 to September 09, 2018).
- NOAA-20 CLAVR-x 24 days (May 02 to September 09, 2018).
- NASA AQUA/MODIS 24 days (May 02 to September 09, 2018).
- CALIPSO Comparison 24 days (May 02 to September 09, 2018).

CALIOP Comparison Description

- CALIOP is a lidar onboard of CALIPSO.
- CALIOP Cloud algorithm results are considered as "Truth".
- 25 days of CALIOP and NOAA-20 Matchup data are used from 2019-022 to 2019-071.



- Filters applied to NOAA-20:
  - Scan time difference ± 12 minutes,
  - Sensor Zenith Angle < 70.0.
- Filters applied to CALIOP:
  - 90N - 90S,
  - COD = 0.0 or > 0.4 (to account for sensitivity difference between lidar and imager),
  - 5km cloud fraction 0 or 1 (to avoid edges of cloud).

CALIPSO Validation of NDE NOAA-20 ECM

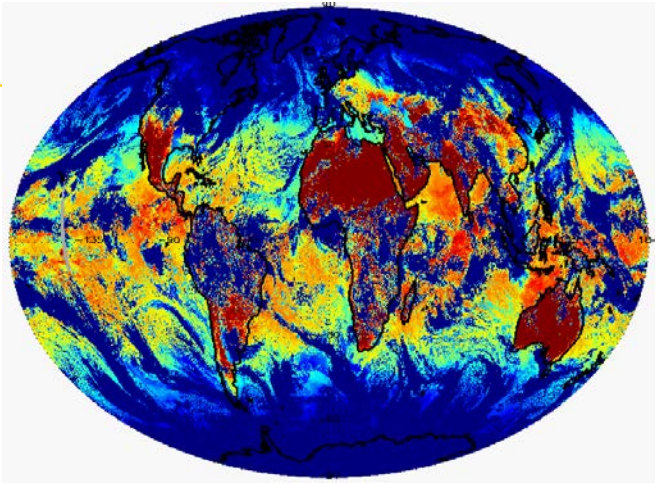
Algorithm	Sample Size	Cloud fraction				Required Detection	Probability of		
		CALIOP	VIIRS	Pr. Clear	Pr. Cloudy		Detection	False Detect.	Missed Cloud
	Global, Ocean/Land, Day/Night, No Snow/Snow/Ice								
ECM NDE	15038573	0.682	0.678	0.127	0.099	0.870	0.880	0.059	0.061
ECM CLAVR-x	15038573	0.682	0.680	0.095	0.087	0.870	0.885	0.060	0.055
	Ocean, Day, Global, No Snow/Snow/Ice								
ECM NDE	6048374	0.723	0.710	0.023	0.024	0.920	0.939	0.025	0.036
ECM CLAVR-x	6048374	0.723	0.705	0.019	0.027	0.920	0.943	0.021	0.036
	Ocean, Night, Global, No Snow/Snow/Ice								
ECM NDE	6283745	0.754	0.767	0.092	0.060	0.900	0.917	0.065	0.018
ECM CLAVR-x	6283745	0.754	0.765	0.090	0.032	0.900	0.925	0.038	0.037
	Land, Day, Global, No Snow/Snow/Ice								
ECM NDE	1854730	0.522	0.493	0.059	0.044	0.900	0.912	0.018	0.070
ECM CLAVR-x	1854730	0.522	0.497	0.048	0.039	0.900	0.914	0.015	0.071
	Land, Night, Global, No Snow/Snow/Ice								
ECM NDE	2018776	0.624	0.563	0.070	0.069	0.880	0.897	0.045	0.058
ECM CLAVR-x	2018776	0.624	0.599	0.072	0.066	0.880	0.901	0.044	0.055

- This stats are calculated based on VIIRS - CALIOP data from 25 days in 2019 (from 2019-022 to 2019-071).
- Both ECM NDE and ECM CLAVR-x meet required specification.

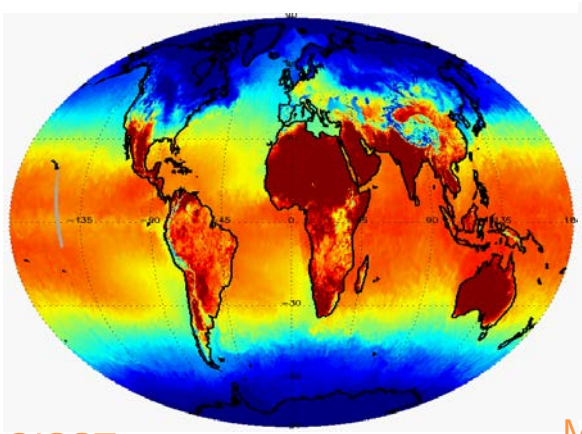
ECM NDE - I&T ECM NDE
ECM CLAVR-x - ECM produced by CLAVR-x
No Snow/Snow/Ice = Snow/Ice Filter Applied

SST Comparison Description

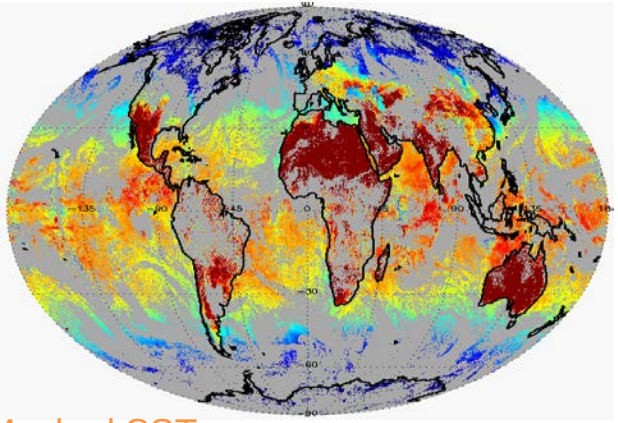
- Sea Surface Temperature (SST) is very sensitive to the presence of cloud.
- If we compute SST for all pixels, we can compare observed SST to a background SST.
- Clear pixels with negative SST biases are likely missed cloud.
- Cloudy pixels with small SST biases are likely false cloud.
- This analysis uses OISST.
- SST computed using NLSST coefficients trained for this analysis.
- Data from 25 days (2019-022 to 2019-071) of NOAA-20 is used.
- Not the NDE SST Product.



SST Unmasked



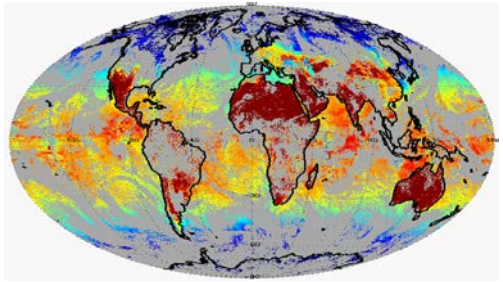
OISST



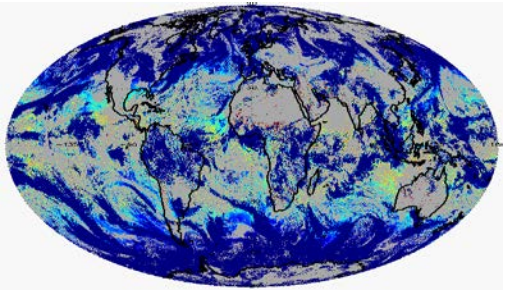
Masked SST

SST Comparison Description

O (observations)

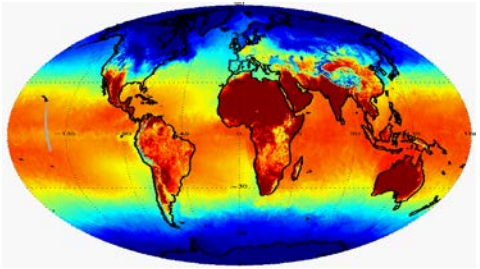


Cloud Masked SST

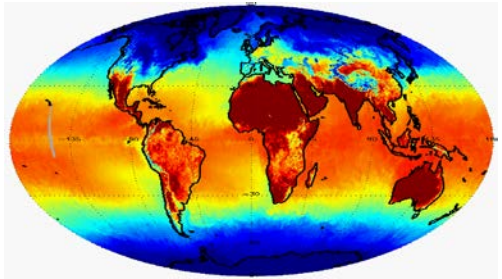


Clear Masked SST

B (background)

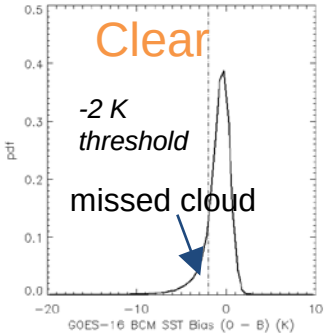


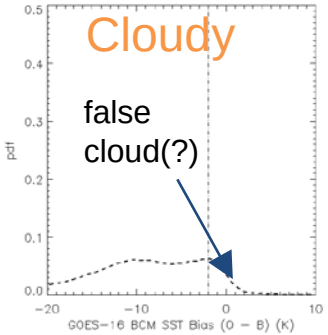
OISST



OISST

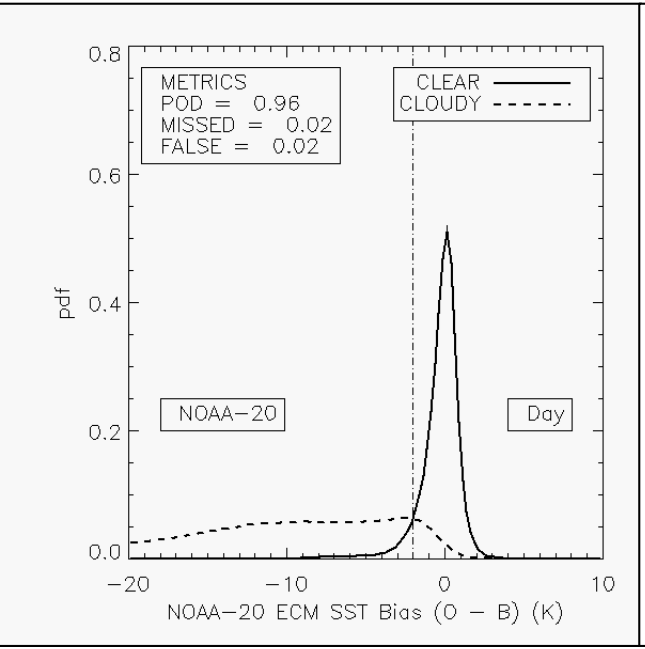
O-B (bias)



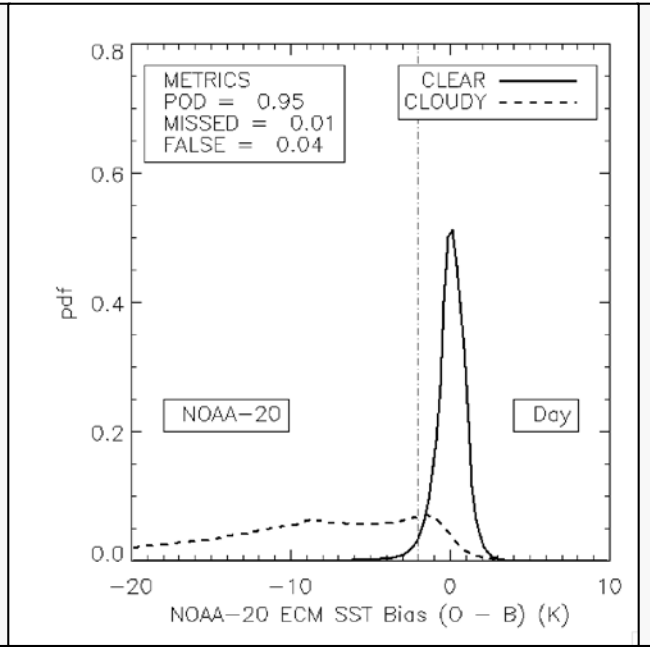


Daytime SST Analysis

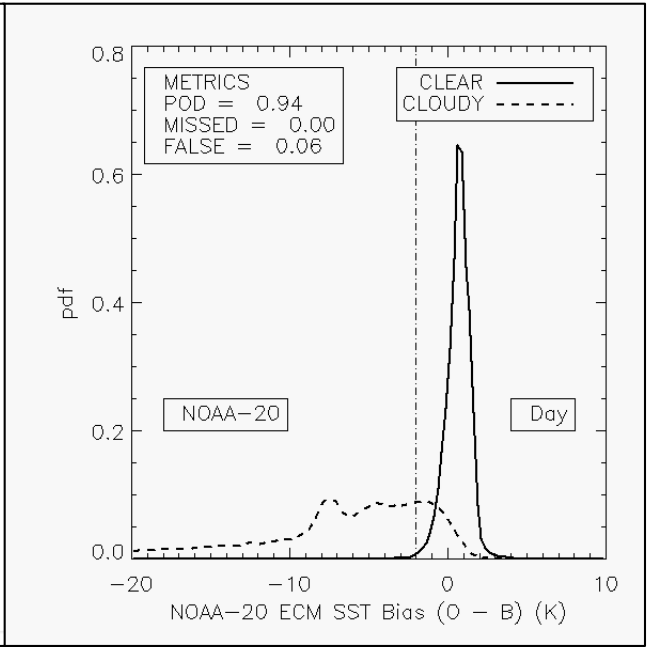
Beta



Provisional



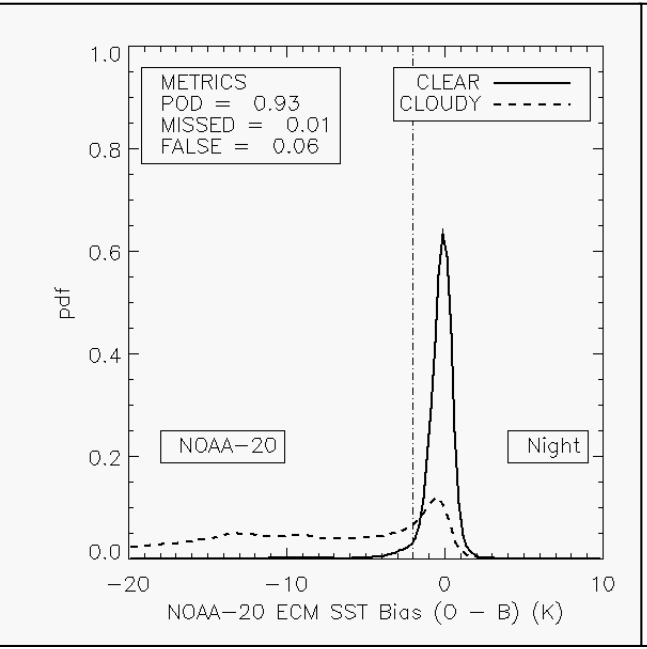
Full Maturity



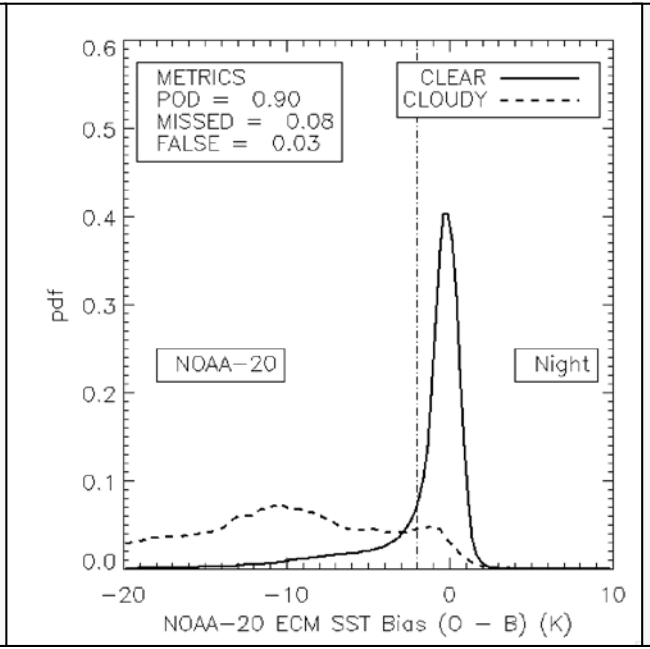
SST analysis shows that ECM meets specs (POD ≥ 0.92).

Nighttime SST Analysis

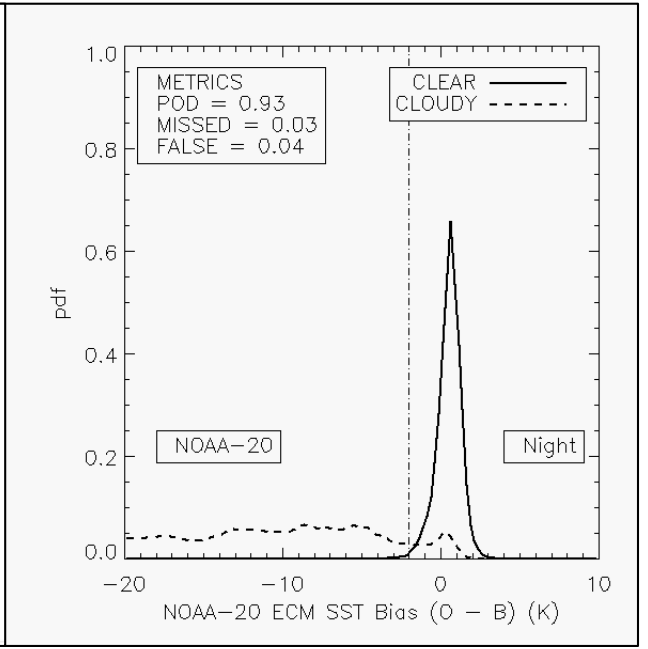
Beta



Provisional



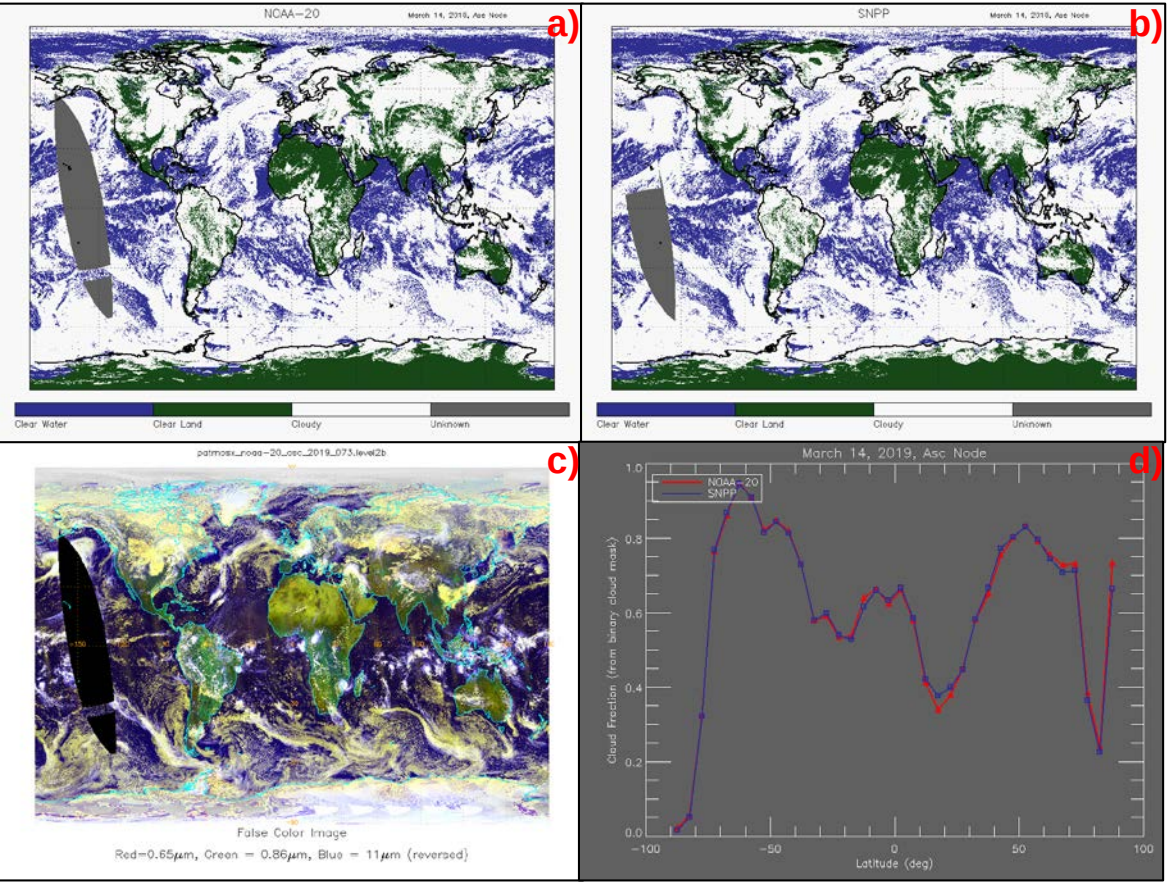
Full Maturity



SST analysis shows that ECM meets specs (POD ≥ 0.90).

Performance Monitoring and SNPP Consistency

Comparison of ECM NOAA-20 vs SNPP



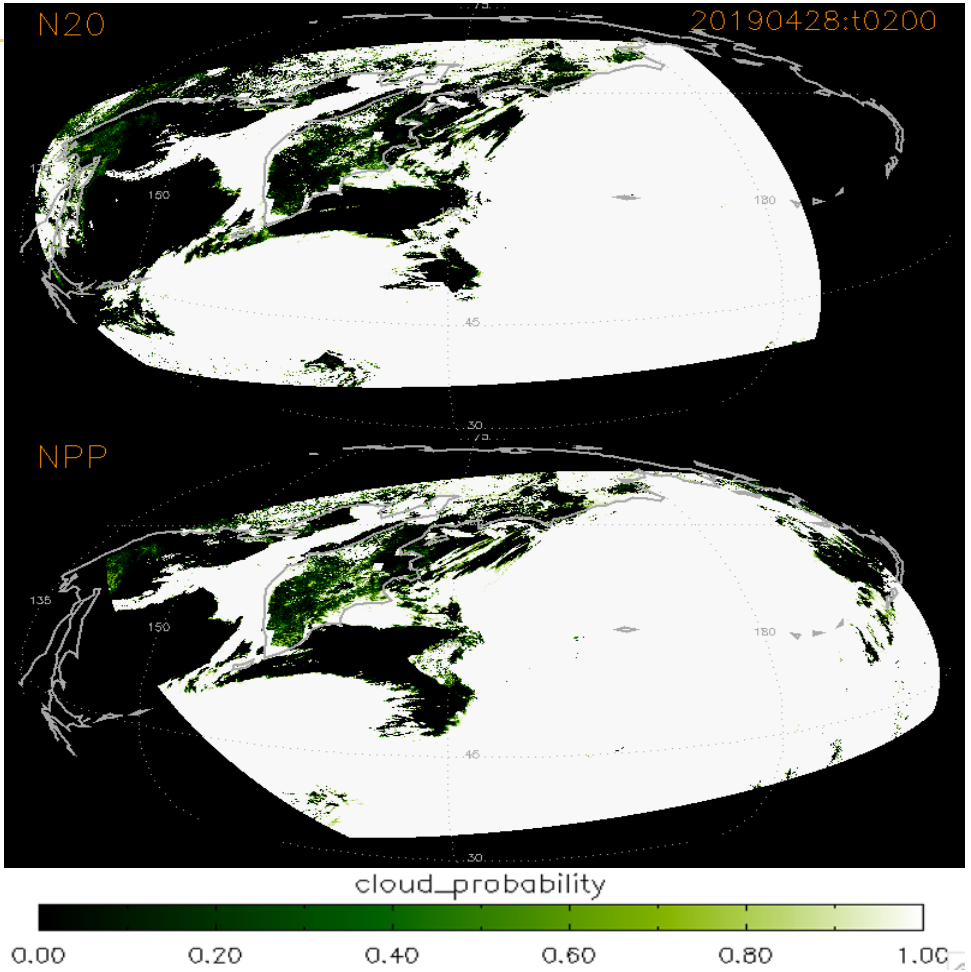
Global Composite, March 14, 2019

a) ECM NOAA-20.
b) ECM SNPP.
c) RGB NOAA-20.
d) Zonal Cloud Fraction.

- Mostly ECM on both NOAA-20 and SNPP perform similarly.
- Differences are seen over cloud edges because of orbit time difference between satellites.
- Zonal Cloud Fraction for both NOAA-20 and SNPP are almost identical.

Visual Comparison of SNPP and N20

- April 28, 2019
- Image shows Cloud Probability for NOAA-20 and SNPP 51 minutes earlier.
- Inspection of all images for this day showed no major inconsistencies.
- Animation on next page.



Visual Comparison of SNPP and N20 (Animation)

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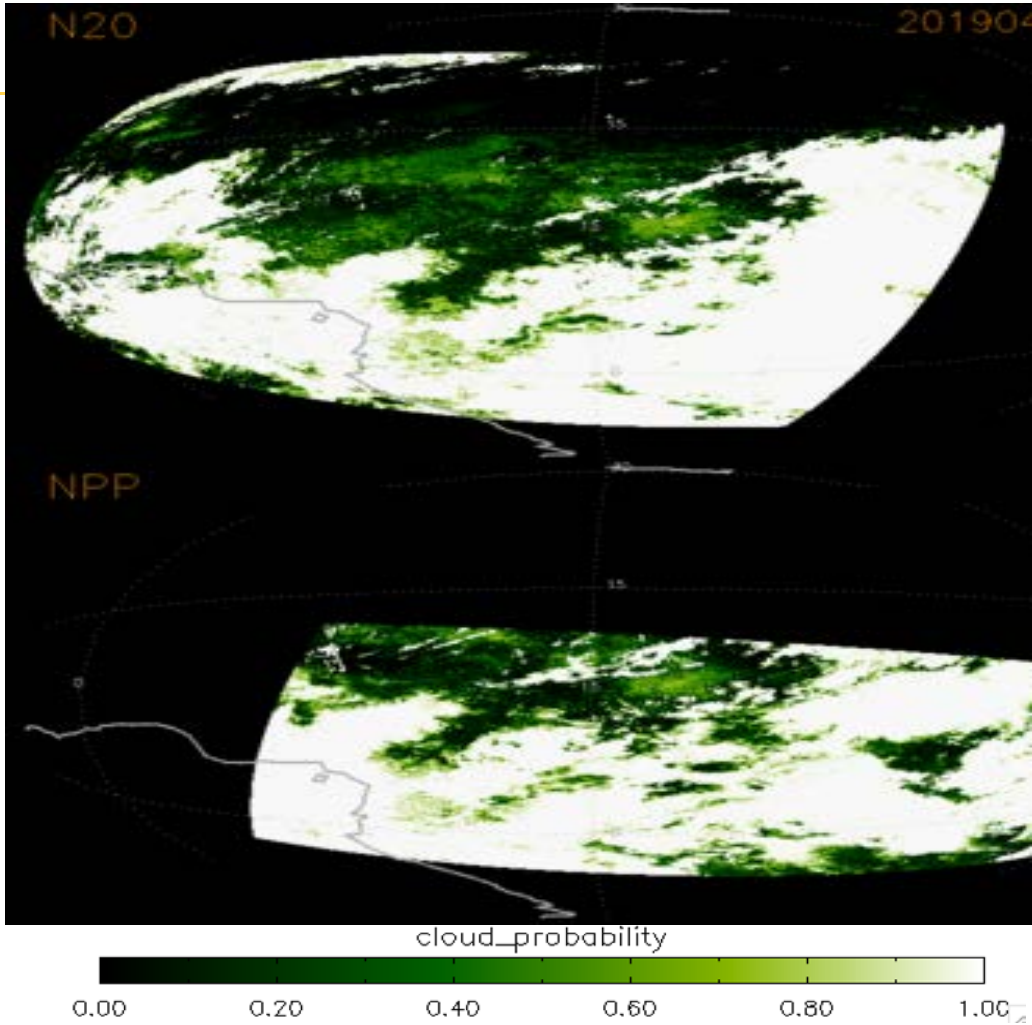
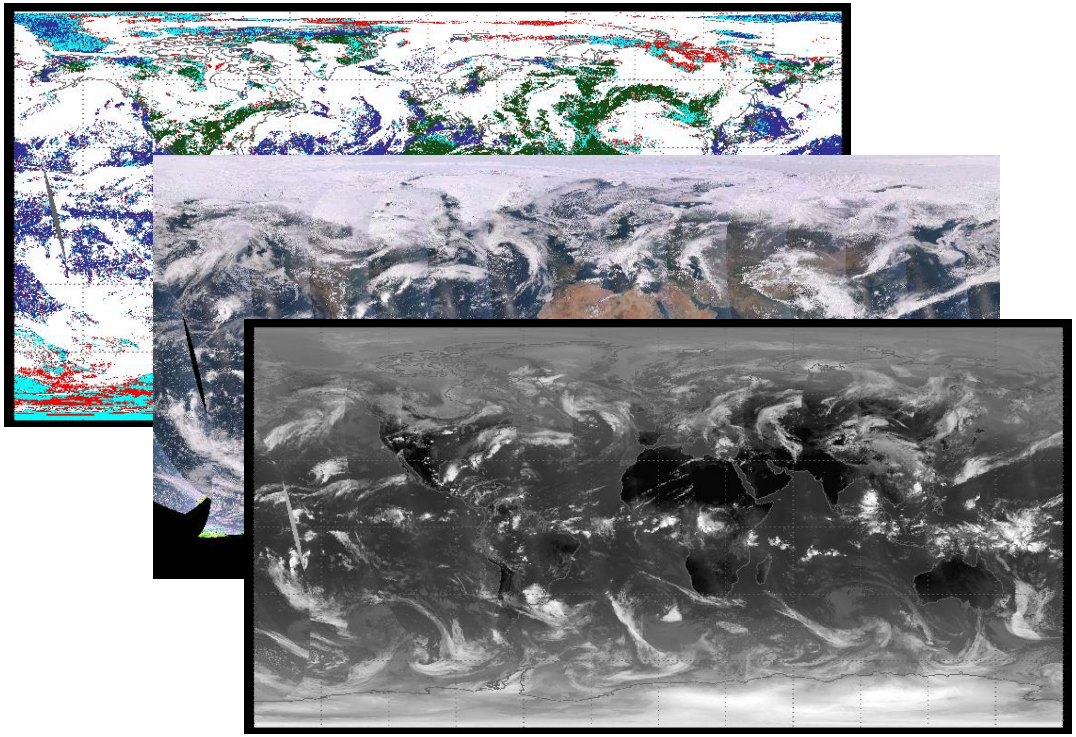


Performance Monitoring

Long Term Monitoring

http://cimss.ssec.wisc.edu/clavrx/viirs_img/



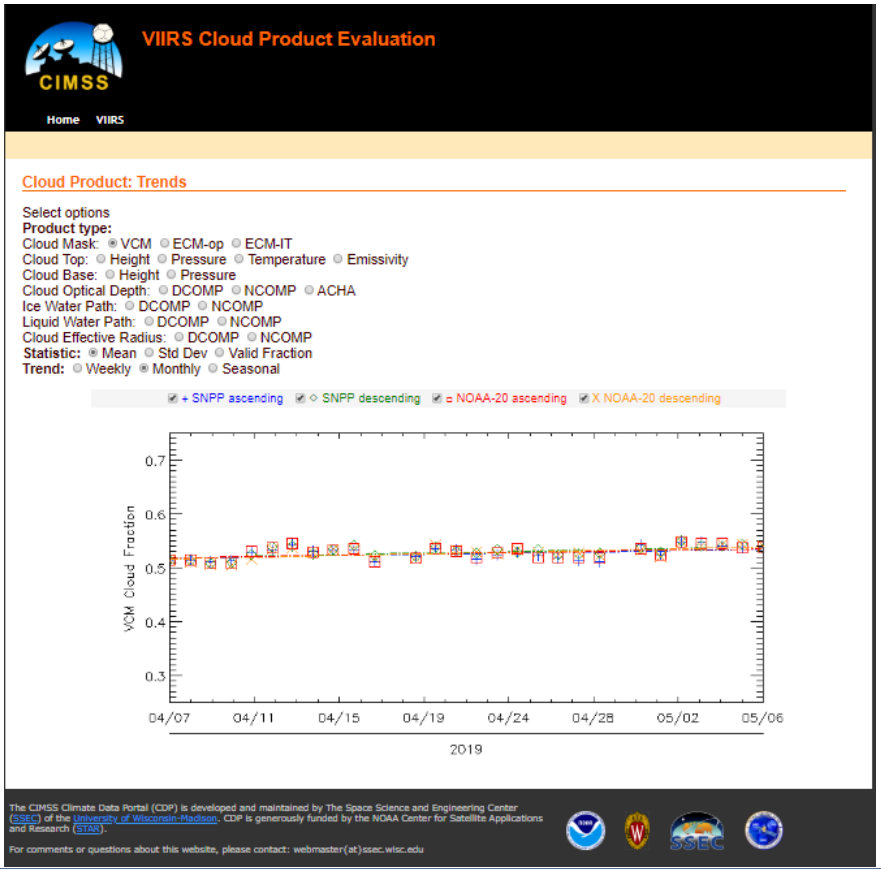
VIIRS Cloud Product Table

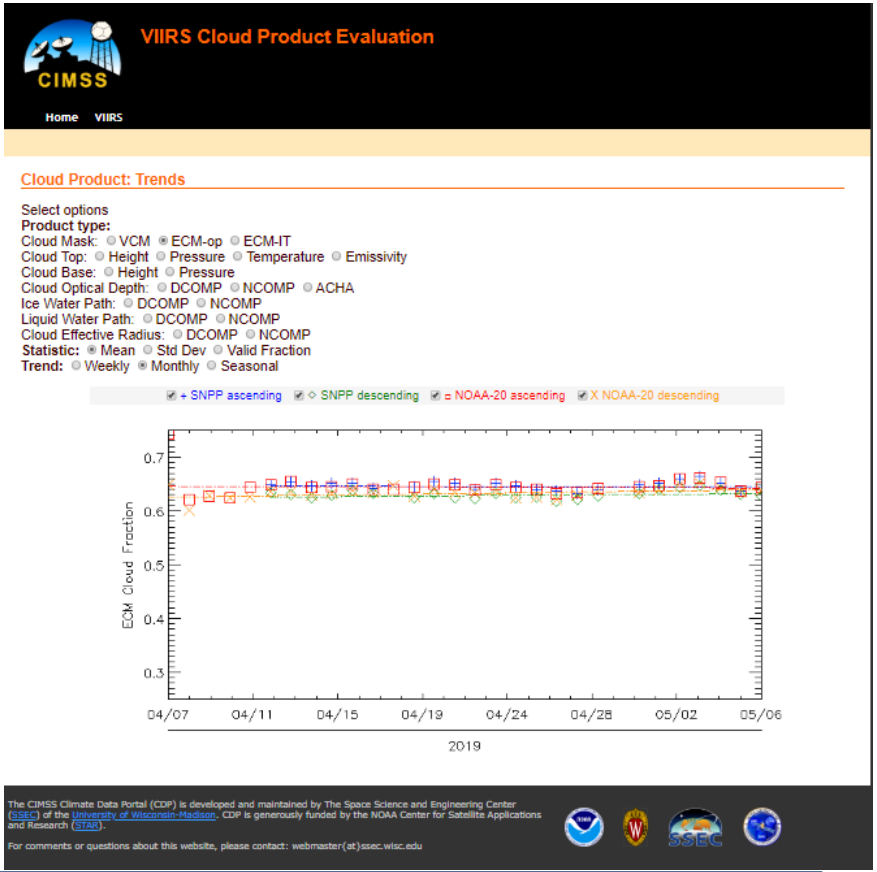
Hover over a thumbnail to view larger image.
Date columns can be adjusted by dropdown menu.

SNPP ASC SNPP DES NOAA-20 ASC NOAA-20 DES

	Latest Avalable	1 day ago	2 days ago	3 days ago	4 days ago
ECM-op (ECM)					
ECM-IT (ECM IT)					
VCM (VCM)					
Red Green Blue (RGB)					
RGBnight					
RGB425					
Ref065					
Ref137					
Ref160					
BT11					
Cloud Optical Depth NCOMP (COD)					
Cloud Optical Depth DCOMP (COD)					
Cloud Optical Depth ACHA (COD)					
Cloud Phase					
Cloud Top Pressure (CTP)					
Cloud Top Temperature (CTT)					
Cloud Top Height (CTH)					

NOAA-20 Ascending VIIRS Cloud Mask Time-Series (VCM-left, ECM-Ops – right)

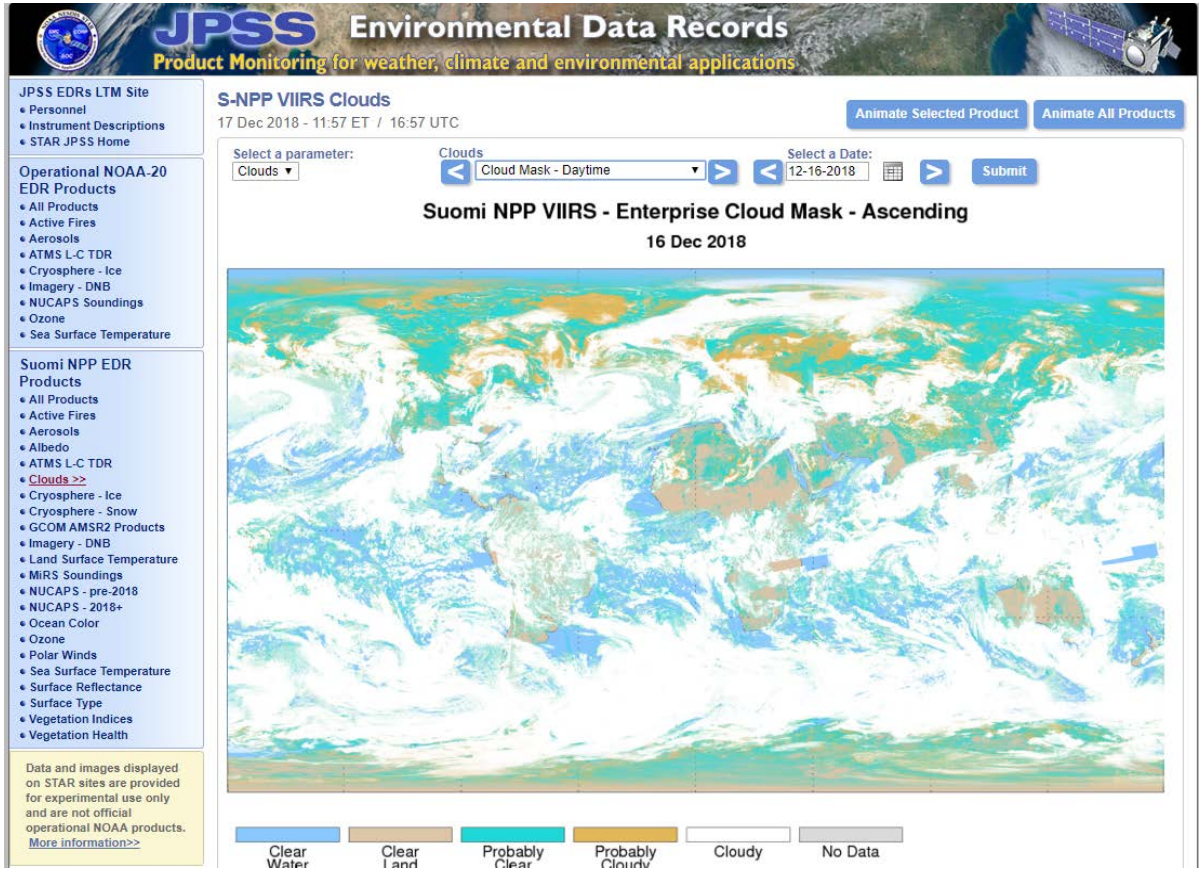




STAR JPSS EDR LTM Site

https://www.star.nesdis.noaa.gov/jpss/EDRs/products_clouds.php

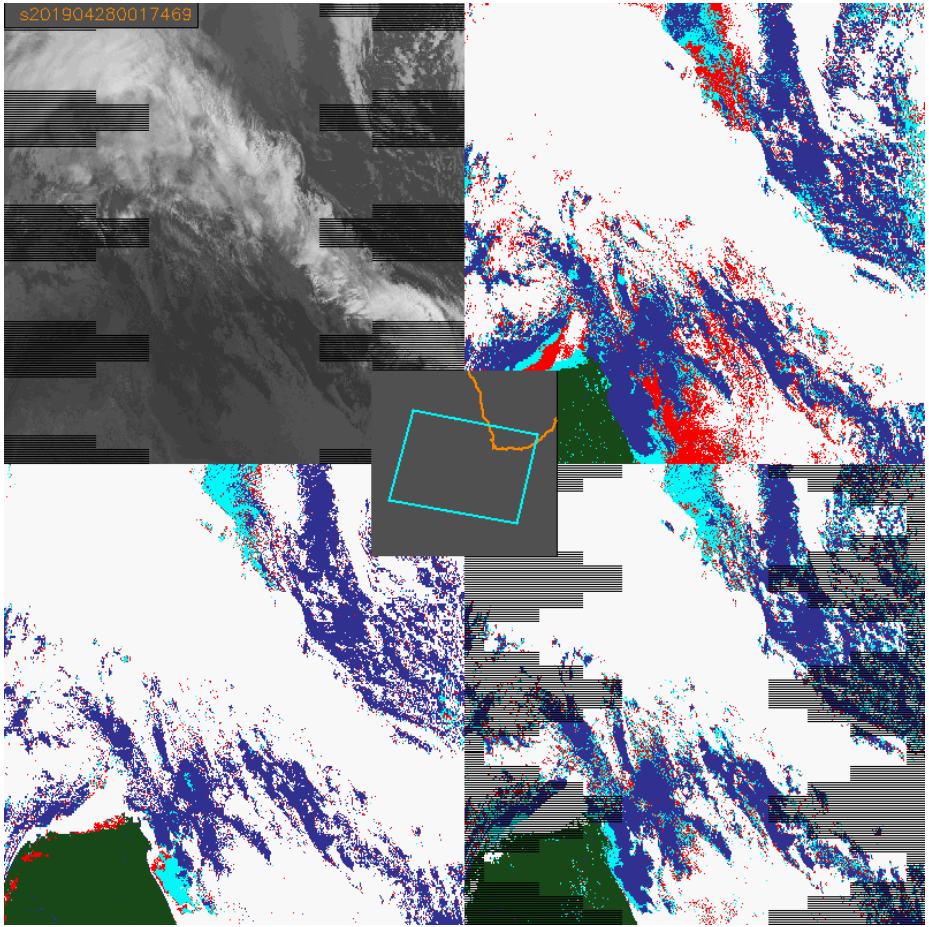
- Cloud Team has stopped making images for the STAR JPSS Site.
- JPSS STAR Team does this now.
- Descending Images and all RGBs are still missing.



Comparison with IDPS VCM and NASA MVCM

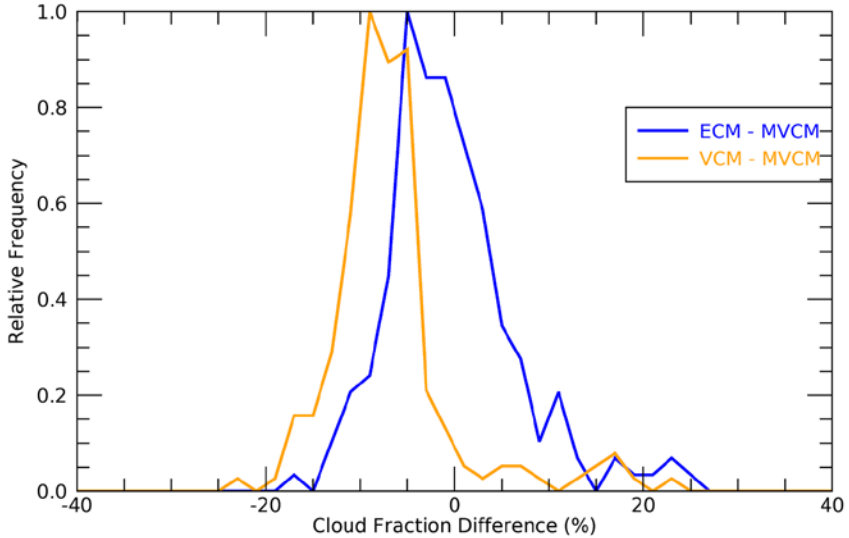
- On SNPP, NASA now makes a cloud mask based on the MODIS heritage called the MVCM (MODIS VIIRS Continuity Mask).
- This offers a new independent source of verification from the ECM.
- Does not exist on NOAA-20 yet.
- These images show one day of matched ECM (top right), MVCM (bottom left) and VCM (bottom right) for April 28, 2019.
- 3 way comparisons are very instructive for finding specific issues.

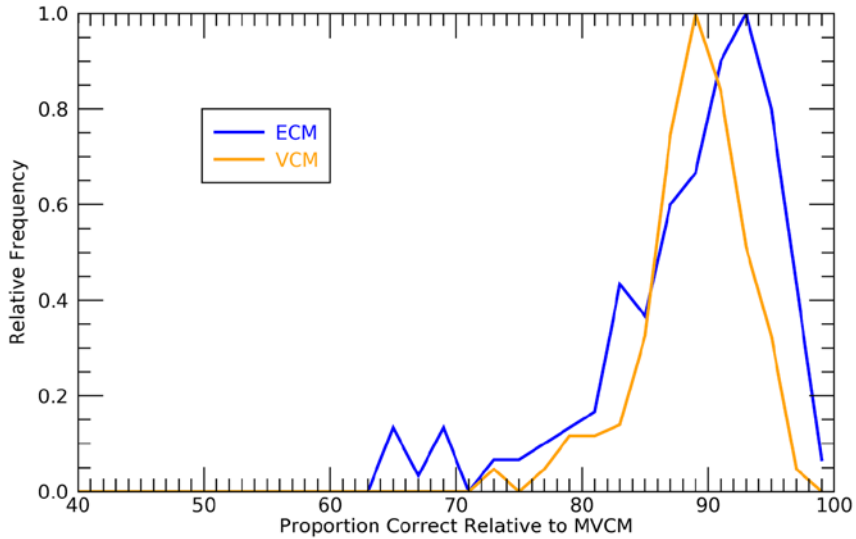
  Each mask has distinctive characteristics.



Comparison with IDPS VCM and NASA MVCM

- ECM Cloud Fraction shows less mean bias wrt MVCM.
- Mean Proportion Correct (PC) values are similar between VCM and ECM
- ECM has more higher PC values and some lower.
- Having MVCM is a nice reference for gauging ECM performance.





Binary Cloud Mask Error Budget

Attribute	JERD Threshold	On Orbit Performance (via CALIOP)	Meet Requirement
Measurement Accuracy (Global, Ocean Day, Ocean Night, Land Day, Land Night, Desert Day, Desert Night, Snow Day, Snow Night, Sea-Ice Day, Sea-Ice Night, Antarctic Day, Antarctic Night)	87%, 92% 90%, 90%, 88%, 85%, 85%, 88%, 85%, 82%, 72%, 80%, 70%	88%, 94%, 92%, 91%, 90%, 89%, 88%, 89%, 85%, 83%, 75%, 80%, 72% (with COD < 0.4)	Yes
Missed Cloud (Leakage)	n/a	6%, 2%, 6%, 2%, 4%, 4%, 5%, 5%, 7%, 7%, 11%, 8%, 13%	n/a
False Cloud	n/a	6%, 4%, 2%, 7%, 6%, 7%, 7%, 6%, 8%, 10%, 14%, 12%, 15%	n/a

Note: COD filter is used to account for sensitivity difference between lidar and imager.

User Feedback

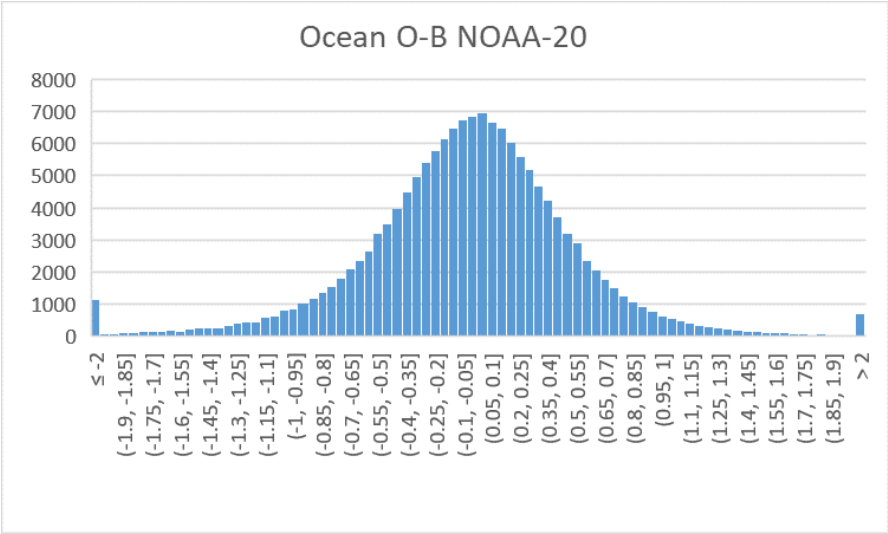
Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations
Jim Jung	NESDIS	All Sky Radiance	See slides (to be delivered by JJ/SN) regarding feedback
Shobha Kondragunta	STAR/Aerosol Team	Dust Mask	Dissatisfaction with ECM dust mask compared VCM dust mask. (tbd) (Should add specs/requirements for the non-cloud mask functions (smoke, dust, shadow, glint and snow).
Shobha Kondragunta	STAR/Aerosol Team	ECM archive	Needs ECM archive from v2 SDR

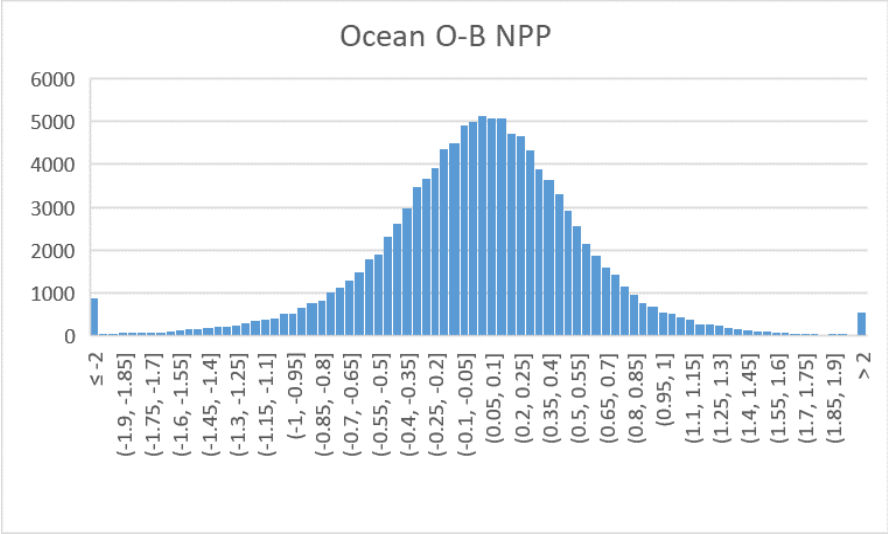
Summary of NCEP Feedback (Jim Jung)

- N20 and SNPP are consistent for the CriS Radiance Classification Application.
- VIIRS Cloud products add value over the internal CrIS cloud detection.
- Issue with asymmetry of clear counts across the CrIS FOR needs investigating.

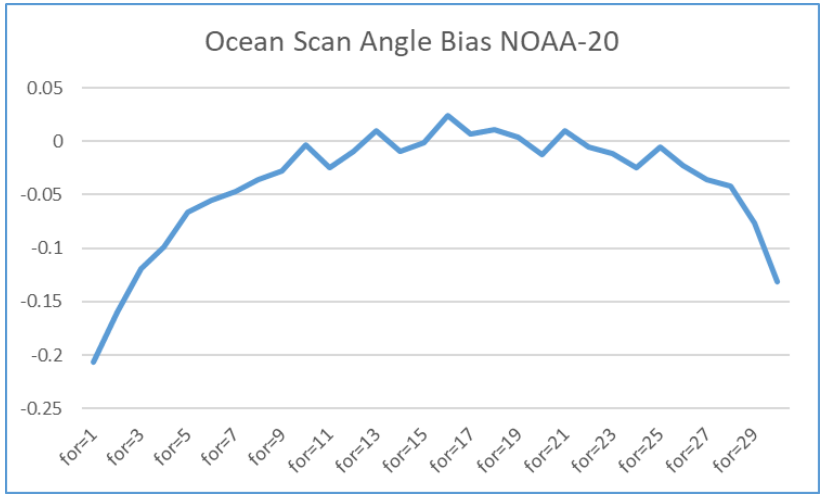
- Clear field of view (FOV) assimilation only.
  - Clear FOV defined as clear + probably clear VIIRS FOVs mapped onto CrIS FOV.
- 17 March – 30 March 2019.
  - NPP data available 17 March – 26 March 2019 (midwave failure).
- Bias correction not applied.
- Results from N20 and NPP are very consistent.

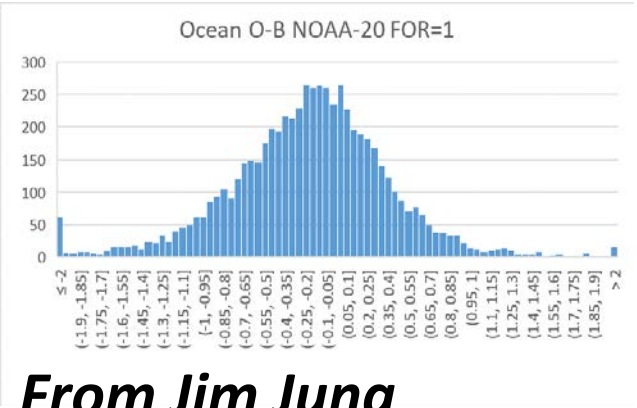
From Jim Jung

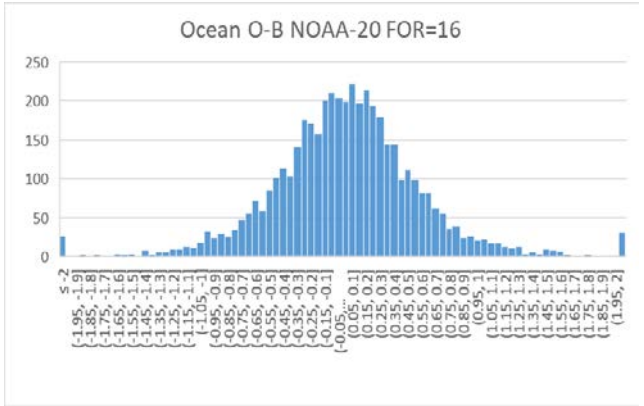


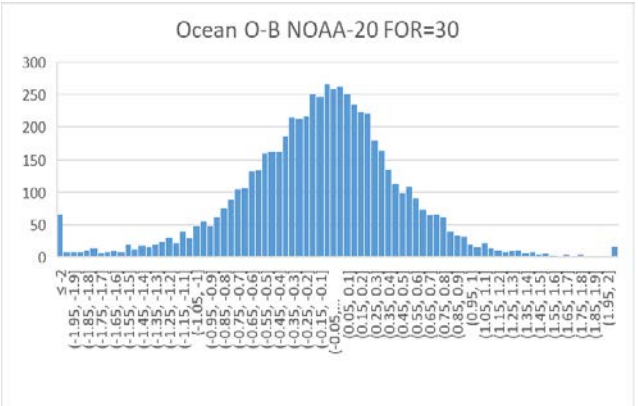


- Angle dependent bias is expected (left).
  - Should be symmetric
- Histograms for each field of regard (FOR) should also be symmetric around mean (bottom).
- Possible missed clouds at high scan angles, especially left side.
- Similar results for other surface types (snow, desert, etc).





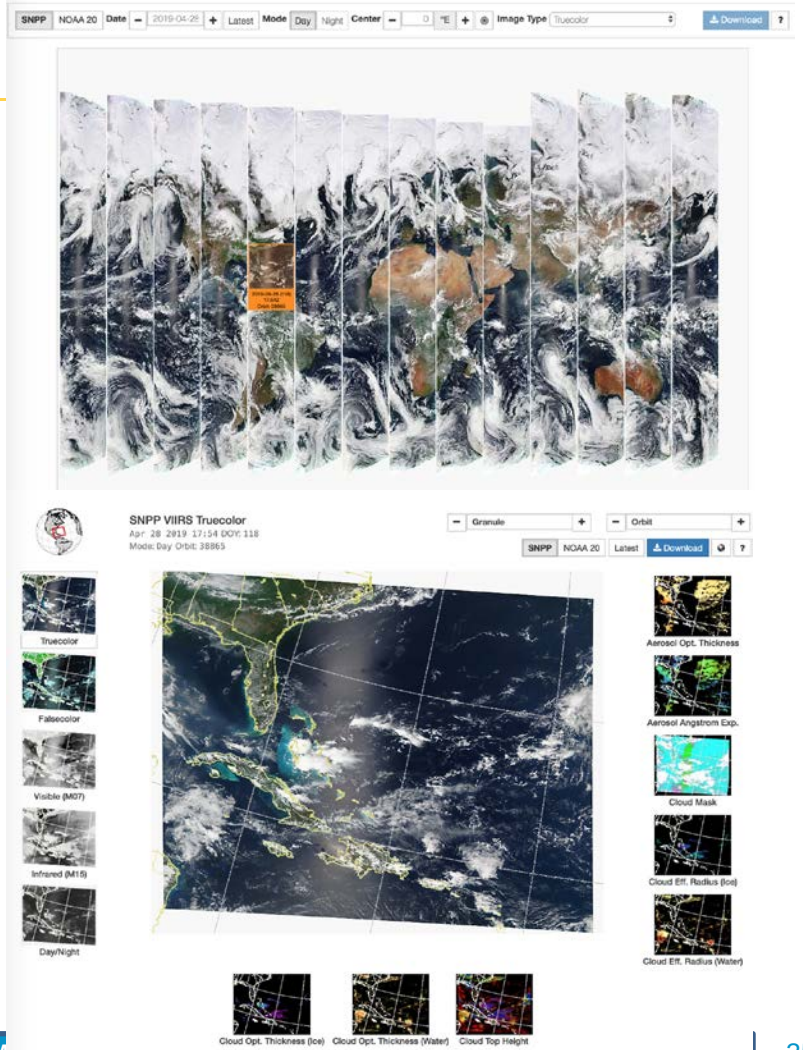




From Jim Jung

External User Issues

- CLASS is hard to use. Users have to search 110+ entries in a menu to select either
  - JPSS VIIRS Products Granule
  - JPSS Visible Infrared Imaging Radiometer Suite Environmental Data Record
  - First is NDE, second is IDPS. Most people select the 2nd since the name is more obvious.
- CLASS files are hard to use
  - NDE file names use a different date / time convention and format than the SDR data.
  - Having lat and lon in every NDE file really adds a burden especially when most external users grab sdrs anyway.
  - The shear number of files is daunting.
- NASA NPP Atmosphere SIPS offers a very nice interface to users looking to browse and gain familiarity.
- Maybe JPSS could pay SSEC or someone to make a JPSS front-end to the CLASS archive.
- If we want external level-2 users, we need more than CLASS.



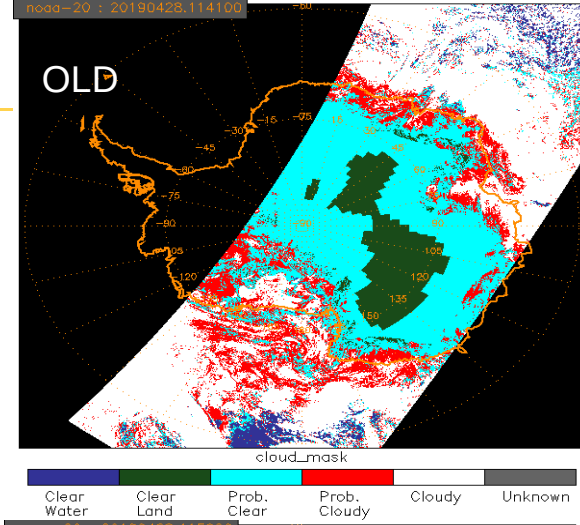
Downstream Product Feedback

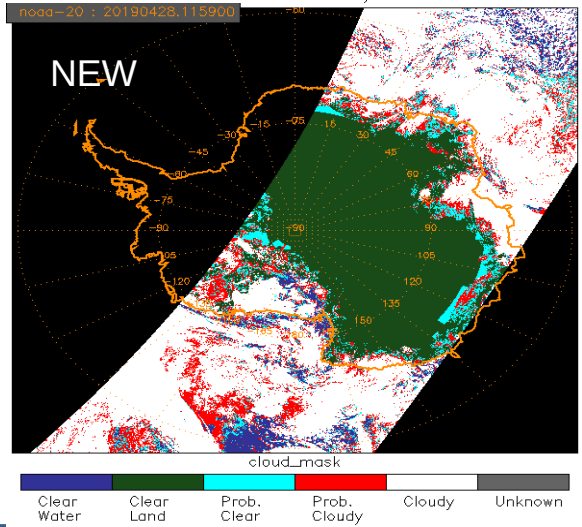
Algorithm	Product	Downstream Product Feedback - Reports from downstream product teams on the dependencies and impacts
Aerosol Team	ECM	Possible over-clouding over land as well as not fully explaining the differences between the v1r1 and v1r2 LUT. ECM Team demonstrated consistency with VCM. LST team stated in Oct 2018 ECM meeting they would provide any further clarification of the issue, if it still exists or is an issue from users.
Ice Surface Temperature/Concentration	ECM	The cryosphere team noted that the initial (v1r2) ECM missed clouds over extremely cold surfaces in the Arctic and Antarctic. The Cryosphere team found from a 2.5 month analysis of most recent delivery (v2r0) found that the cloud mask was much **improved** compared to older (v1r2). There was still some minor issues of questionable sea ice concentration retrievals on limited pixels, which might be due to cloud leakage or ice concentration algorithm itself. The Cryosphere Team will be working with the Cloud team as they continue to investigate this.
Arctic (General)	ECM	Over-detection of cloud in the presence of sea-ice leads.
Snow	ECM	Lack of confident clear in some areas. (see next slide)

Slides with specific information in the Backup Material

User Issue: Not enough Confident Clear (*aka Impact of Surface Type Dependant Thresholds on Prob Clear / Prob Cloudy*)

- Fundamental product of ECM is the cloud probability.
- Mask is derived from the probability. Binary Mask is defined at 50/50. 4-Level Mask was defined at 0/10/50/90/100.
- Some surfaces sometimes never yield cloud probabilities near zero and therefore produce little “confident clear”.
- Our wishes where that users would define confident clear themselves based on their analysis of cloud probabilities for their applications.
- That is not happening and user want a 4-level mask with confident clear everywhere.
- So we redefined the conf/prob thresholds to ensure that 25% of the binary clear pixels are classified as confidently clear (on average for each surface type).
- Impact is shown on the right (old on top,new on bottom). Antarctic night is the worst example of this.
- Has no impact on the binary mask and therefore our specs.
- Code needs to be updated for this to happen.





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.
Incorrect LUT	There were issues with the generation of the ECM LUT resulting in missing clouds	High	Closed - Issue resolved as of Nov 2018 integration of corrected LUT allowing sufficient time for full validation analyses.
NOAA-20 LUT	A NOAA-20 LUT was generated in April 2019	Low	In Process - Lack of a code update until late 2019 may push this implementation into operations in early 2020

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 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

- Full Provisional analysis utilizing CALIPSO shows that ECM meets specs.
- The MODIS and SST analysis shows continued good performance.
- User feedback is generally positive.
- **The Cloud Team recommends Full Maturity at this time.**

Path Forward

- Next delivery plans:
  - NOAA-20 LUT delivery.
  - New LUT format which will allows for easier modification of attributes such as probably clear, cloudy, cloudy thresholds for surface types (Fall 2019 science code delivery).
  - We would like to have more diagnostic information as metadata:
    - An attribute with which ECM LUTs were used (in work).
    - An attribute with the code version that was used.
    - An attribute that tells us which channels were used.

- Future plans (as they become available in the SAPF):
  - Use of DNB Lunar Reflectance is included in code. While not in SAPF 1.0, this capability is currently being worked on by ASSISTT within SAPF 2.0.
  - We would also like to use the I-Band stats.
  - New flexible test results output.
  - Incorporate feedback from users as they become available.

- Long term monitoring will continue on a routine basis.

Backup Material

JERD Requirements (1)

- JERD-2429 The algorithm shall produce a cloud mask product that has a horizontal cell size of 0.8 km at Nadir.
- JERD-2478 The algorithm shall produce a cloud mask product that has a horizontal reporting interval the same as the cloud mask horizontal cell size.
- JERD-2479 The algorithm shall produce a cloud mask product that has a mapping uncertainty, (3 sigma) of 4 km.
- JERD-2480 The algorithm shall produce a cloud mask product that has measurement range of cloudy/not cloudy.

JERD Requirements (2)

- JERD-2481 The algorithm shall produce a cloud mask product that has a probability of correct typing of:
  - 87% Globally,
  - 92% Ocean, Day,
  - 90% Ocean, Night,
  - 90% Snow-free Land, Day,
  - 88% Snow-free Land, Night,
  - 85% Desert, Day,
  - 85% Desert, Night,
  - 88% Snow-covered land, Day,
  - 85% Snow-covered land, Night,
  - 82% Sea-Ice, Day,
  - 72% Sea-Ice, Night,
  - 80% Antarctica and Greenland, Day, and
  - 70% Antarctica and Greenland, Night.

Executive Summary

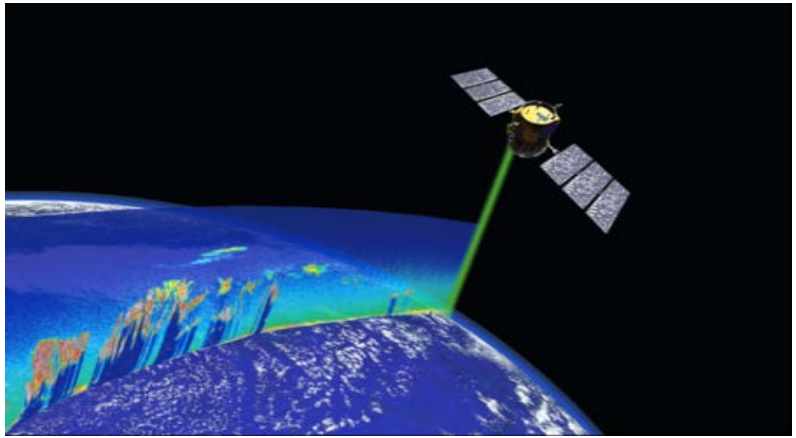
- There is NO significant difference in results between Provisional and this review.
- Full Validation analysis utilizing CALIPSO shows that ECM meets specs over all conditions, same as at the past Provisional review.
- The MODIS and SST analysis shows continued good performance.

Summary of Issues from Provisional

Issue	Status	Comment
NDE processing issues (Missing granules)	FIXED	Implemented in v2r0. Currently in operational string as of late Jan 2019
Similar SDR for NPP issues as beta (M5 is 5% too bright)	Ongoing	
Missing low cloud at night	FIXED	This was due to a LUT generation issue. The corrected LUT was implemented into the I&T string in Nov 2018 and is currently in Ops

CALIOP Comparison Description

- CALIOP is a lidar onboard of CALIPSO.
- CALIOP Cloud algorithm results are considered as “Truth”.
- 25 days of CALIOP and NOAA-20 Matchup data are used from 2019-022 to 2019-071.
- Filters applied to NOAA-20:
  - Scan time difference ± 12 minutes,
  - Sensor Zenith Angle < 70.0.
- Filters applied to CALIOP:
  - 90N - 90S,
  - COD = 0.0 or > 1.0,
  - 5km cloud fraction 0 or 1 (to avoid edges of cloud).



CALIPSO Validation of NDE NOAA-20 ECM

Algorithm	Sample Size	Cloud fraction				Required Detection	Probability of		
		CALIOP	VIIRS	Pr. Clear	Pr. Cloudy		Detection	False Detect.	Missed Cloud
	Global, Ocean/Land, Day/Night, No Snow/Snow/Ice								
ECM NDE	14737802	0.682	0.675	0.125	0.097		0.914	0.035	0.051
ECM CLAVR-x	14737802	0.682	0.677	0.097	0.085		0.915	0.038	0.047
	Ocean, Day, Global, No Snow/Snow/Ice								
ECM NDE	5927407	0.721	0.703	0.034	0.041	0.940	0.961	0.022	0.017
ECM CLAVR-x	5927407	0.721	0.701	0.025	0.031	0.940	0.962	0.019	0.019
	Ocean, Night, Global, No Snow/Snow/Ice								
ECM NDE	6158070	0.752	0.764	0.089	0.071	0.850	0.922	0.054	0.024
ECM CLAVR-x	6158070	0.752	0.761	0.085	0.044	0.850	0.931	0.027	0.042
	Land, Day, Global, No Snow/Snow/Ice								
ECM NDE	1817635	0.541	0.512	0.062	0.051	0.900	0.930	0.025	0.045
ECM CLAVR-x	1817635	0.541	0.520	0.057	0.045	0.900	0.929	0.021	0.050
	Land, Night, Global, No Snow/Snow/Ice								
ECM NDE	1978400	0.621	0.574	0.069	0.075	0.880	0.912	0.041	0.047
ECM CLAVR-x	1978400	0.621	0.595	0.071	0.072	0.880	0.911	0.042	0.047

- This stats are calculated based on VIIRS - CALIOP data from 25 days in 2019 (from 2019-022 to 2019-071).
- Both ECM NDE and ECM CLAVR-x meet required specification.

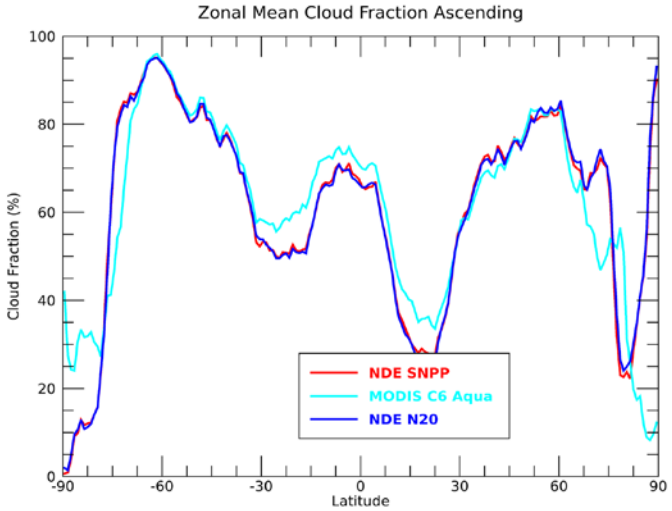
ECM NDE - I&T ECM NDE
ECM CLAVR-x - ECM produced by CLAVR-x
No Snow/Snow/Ice = Snow/Ice Filter Applied

Binary Cloud Mask Error Budget using L1RD

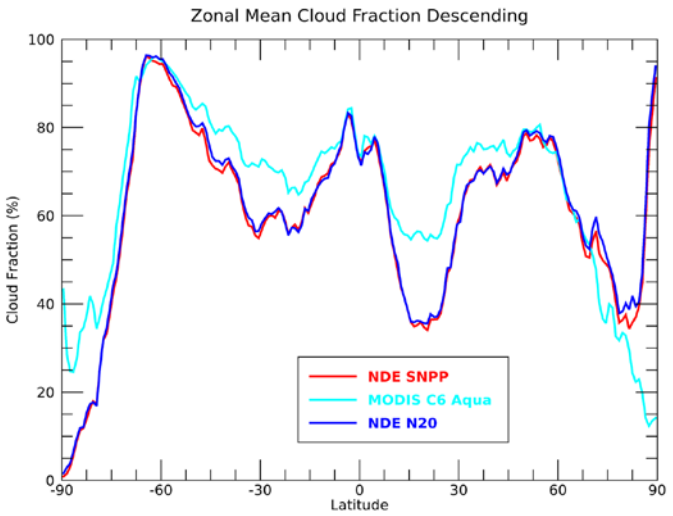
Attribute	JERD Threshold	On Orbit Performance (via CALIOP)	Meet Requirement
Measurement Accuracy (Ocean Day, Ocean Night, Land Day, Land Night) (with COD < 1.0)	94%, 85% 90%, 88%	96%, 92%, 93%, 91%	Yes
Missed Cloud (Leakage) (Ocean Day, Ocean Night, Land Day, Land Night)	1%, 5%, 3%, 5%	2%, 5%, 2%, 4%	Yes, except Ocean Day.
False Cloud (Ocean Day, Ocean Night, Land Day, Land Night)	5%, 8%, 7%, 8%	2%, 2%, 4%, 5%	Yes

Note: COD filter is used to account for sensitivity difference between lidar and imager.

MODIS Comparison



Daytime

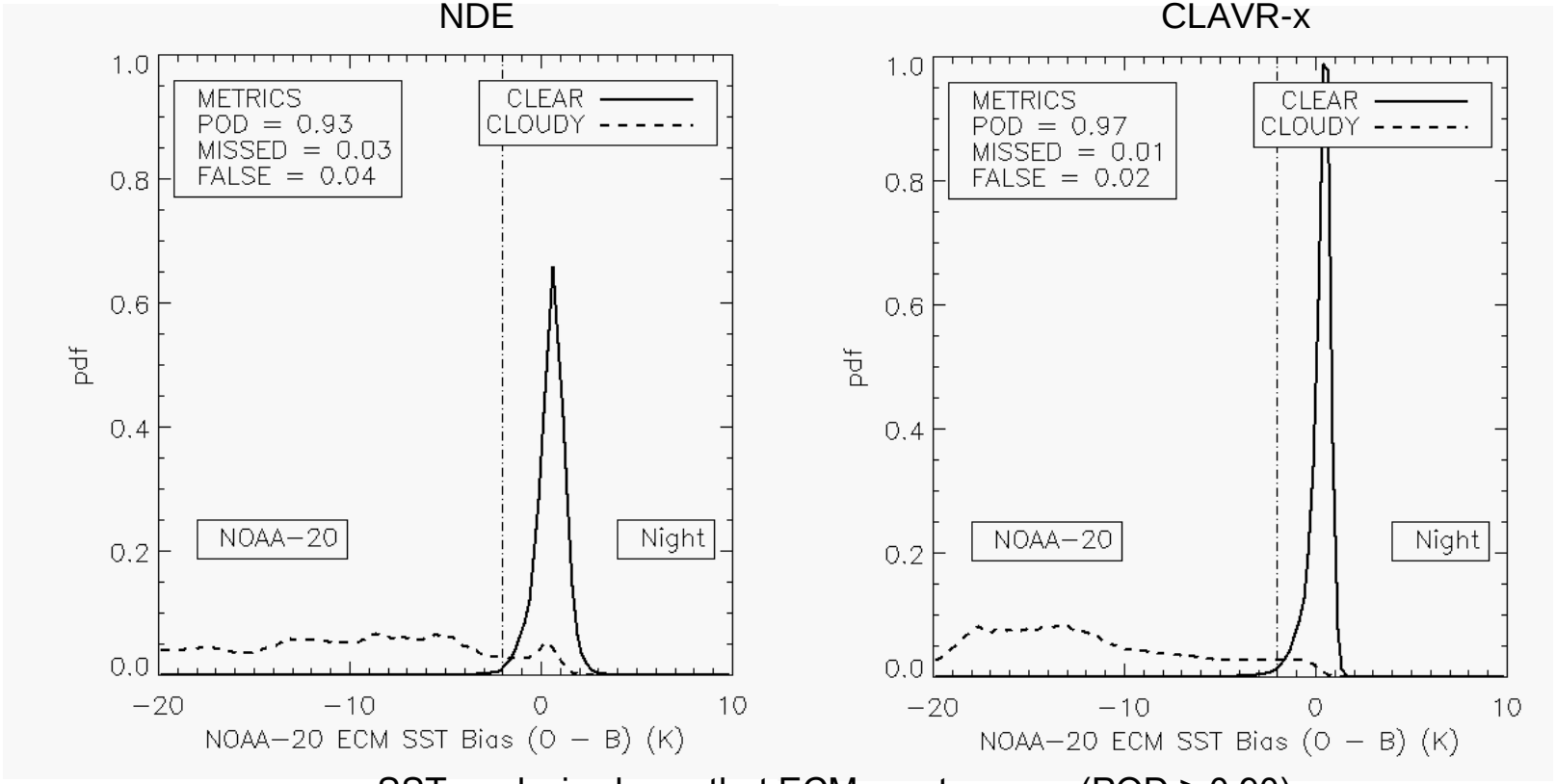


Nighttime

- ECM Cloud Fraction for both NOAA-20 (blue) and SNPP (red) are almost identical for both daytime (left image) and nighttime (right image).

- MODIS C6 Cloud Fraction (cyan) is different than ECM VIIRS, but this is consistent to what we saw for Provisional review and new LUT analysis in November 2018.

Comparison of NDE and CLAVR-x Night SST Analysis

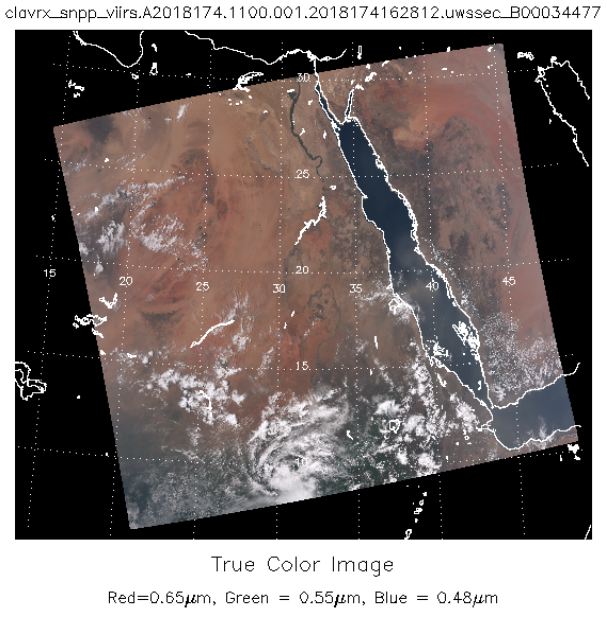


SST analysis shows that ECM meets specs (POD ≥ 0.90)

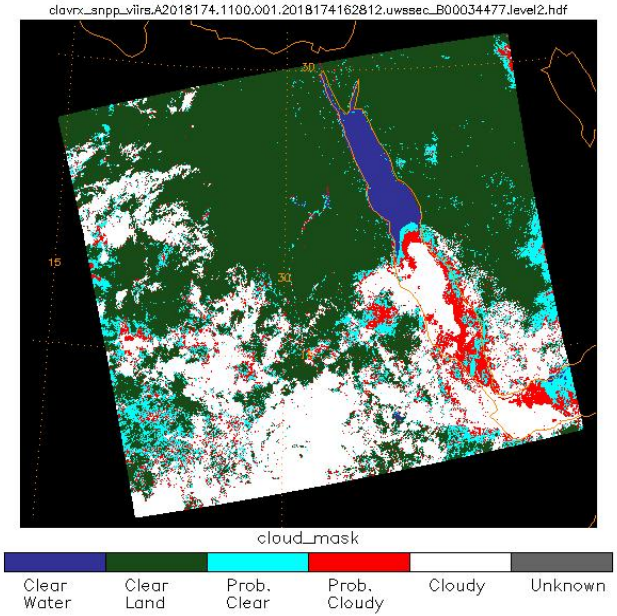
User interactions with Aerosol Team

Red Sea issue (2018 Annual meeting Breakout)

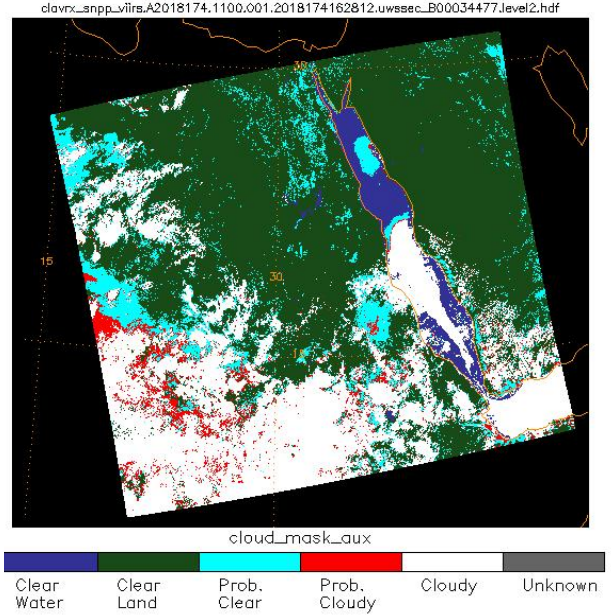
- At the JPSS annual meeting, our understanding is the issue Lorraine Remer brought up was regarding possible over-clouding over land as well as not fully explaining the differences between the v1r1 and v1r2 LUT. This was particularly noticeable for the 1101 UTC granule on 23 June, 2018, particularly over the Sudan/Eritrea border region



True color



ECM



VCM

Red Sea Issue Conclusions

- There while there were differences in the v1r1 and current LUTs which increased the cloud probabilities, particularly the regions along the western edge of the Red Sea and the Sudan/Eritrea border region.

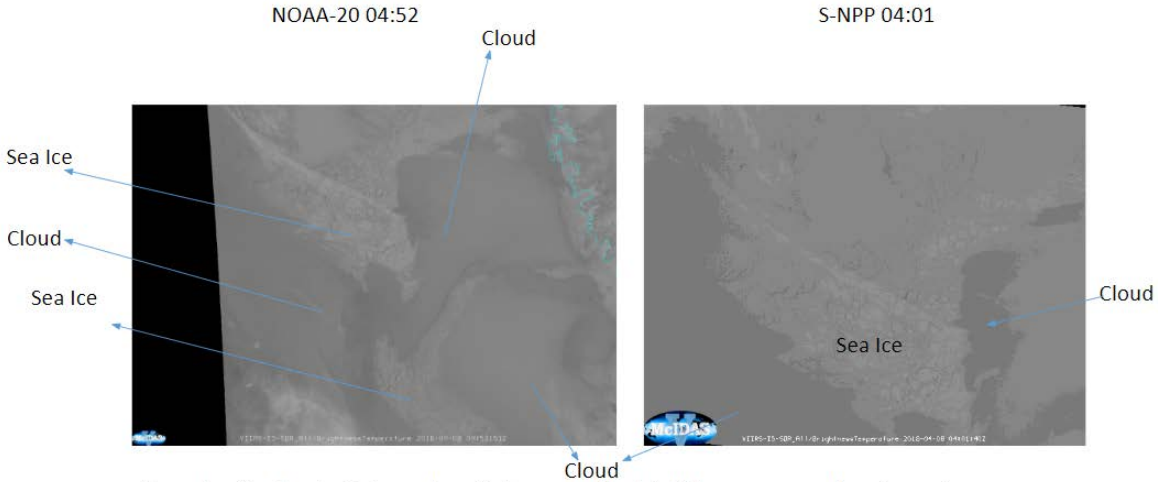
- There is consistency between the current LUT (based on SNPP and uses a MODIS prior and the NASA MODIS VCM for the same scene.

- While there was no further response after the ECM team presented it’s analysis at the October 2018 ECM users meeting, the ECM team appreciate any clarification if our understanding of the issue, if it still exists or is an issue from users.

User interactions with Cryosphere team

Cryosphere Issue

- An initial look at the issue indicates that there were warm low clouds that were being missed over extremely cold surfaces.



- Examples of surface Ice features alongside low warm clouds in I5 from same granule as in previous slide, but over Weddell Sea (Other side of Antarctic Peninsula)

Cryosphere Issue

- After the new (corrected) LUT was implemented in the SAPF, the teams were asked to perform an evaluation of the 2.5 month run of their products before delivery to NDE.

- Per the cryosphere teams analysis these issues were primarily in the southern hemisphere, while the northern hemisphere looked much improved.

- As stated in their analysis “Cloud mask **has improved much compared to previous version**. There are some minor issues of questionable sea ice concentration retrievals on limited pixels, which might be due to cloud leakage or ice concentration algorithm itself. We will address these issues by collaboration with cloud team. ”

- We look forward to continued interaction with the cryosphere team to address any outstanding issues.

What is Missing

- Impact of new prob clear / prob cloudy
- VCM comparisons

Future Plans of ECM

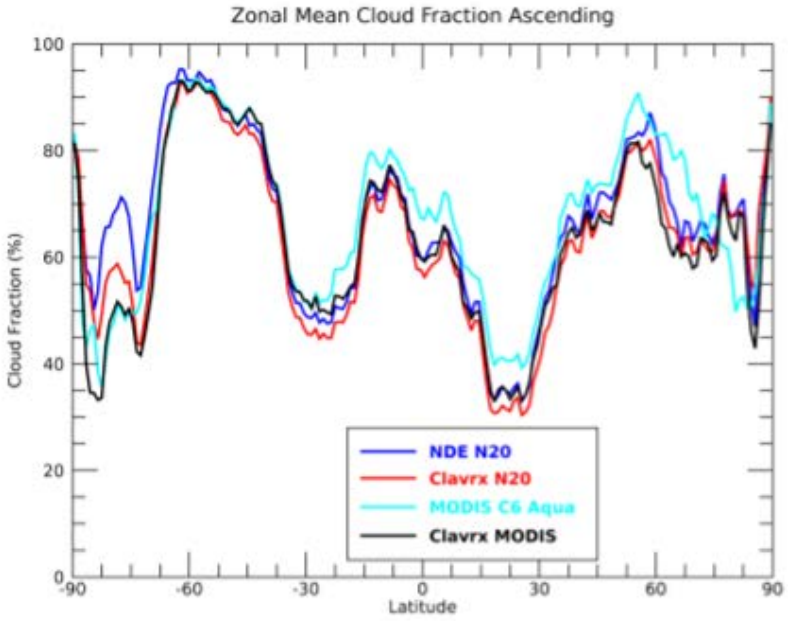
- Next delivery plans:
  - NOAA-20 LUT delivery (April 2019).
  - Modify probably clear, cloudy, cloudy thresholds for surface types
  - Add more information into LUTs to make updates easier
  - Use of 2-D Luts
    - Currently coded in delivered ECM but requires flexible bits. This is needed since the ECM runs on many sensors and will evolve.
    - Will require a new variable that tells which tests were on and adjust the packed bits based on that attribute.
    - Will first be coded and tested in CLAVR-x by summer 2019 for implementation into SAPF late 2019, early 2020.
  - We would like to have more diagnostic information as metadata
    - An attribute with which ECM LUTs were used.
    - An attribute with the code version that was used.
    - An attribute that tells us which channels were used.

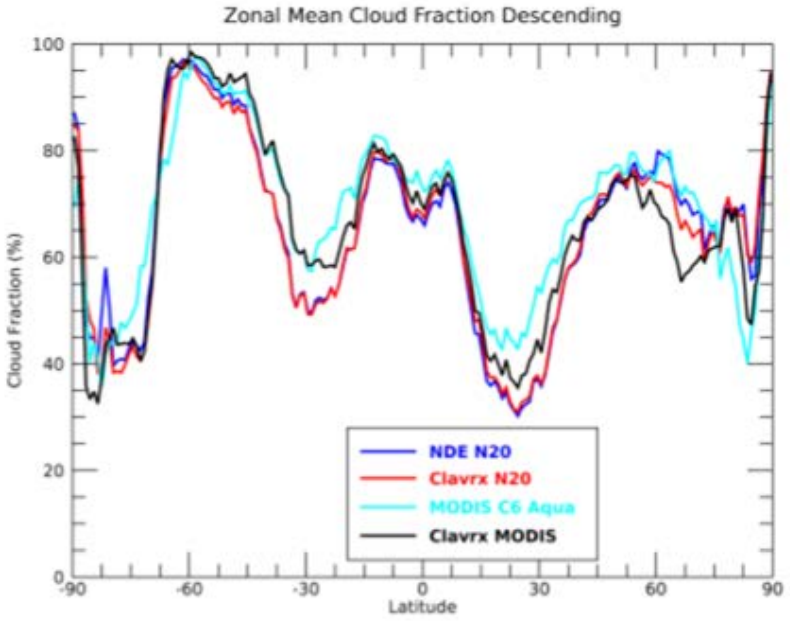
- Future plans (as they become available in the SAPF):
  - Use of DNB Lunar Reflectance is included in code. While not in SAPF 1.0, this capability is currently being worked on by ASSISTT within SAPF 2.0. This will help with cloud detection at night.
  - We would also like to use the I-Band stats.

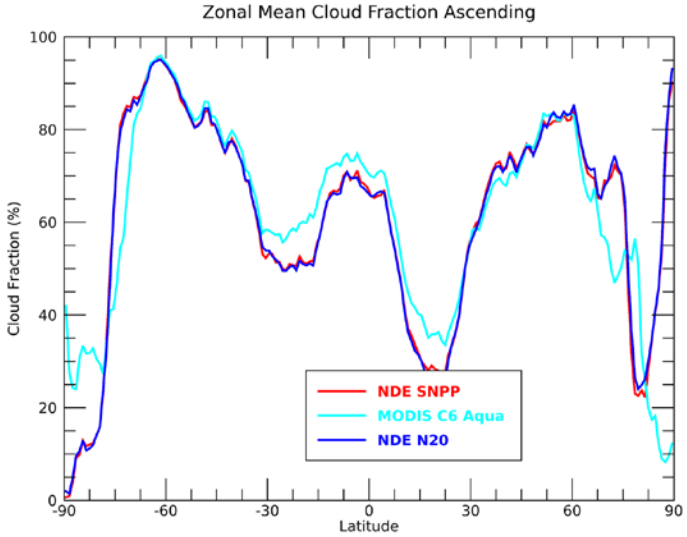
Conclusions

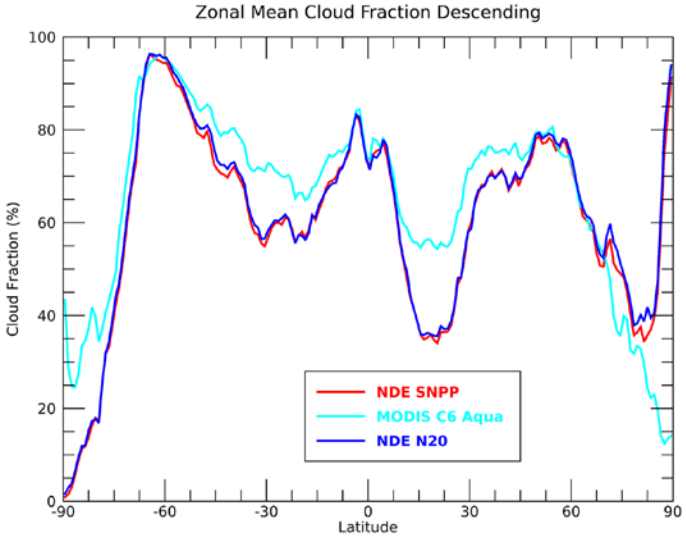
- Full Provisional analysis utilizing CALIPSO shows that ECM meets specs.
- The MODIS and SST analysis shows continued good performance.
- **The Cloud Team recommends Full Maturity at this time.**

Zonal Distribution of Cloud Fraction
From 12 Nov 2018 new LUT analysis

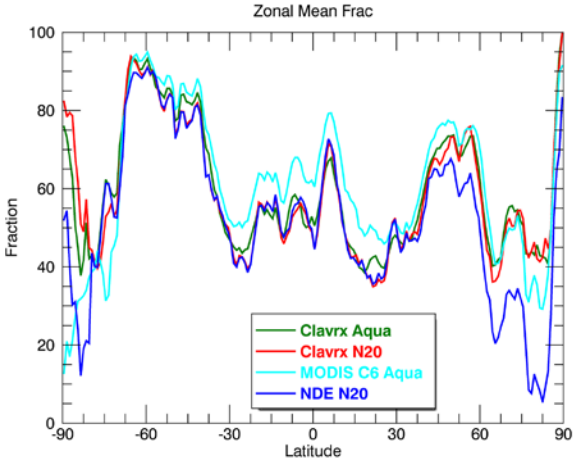




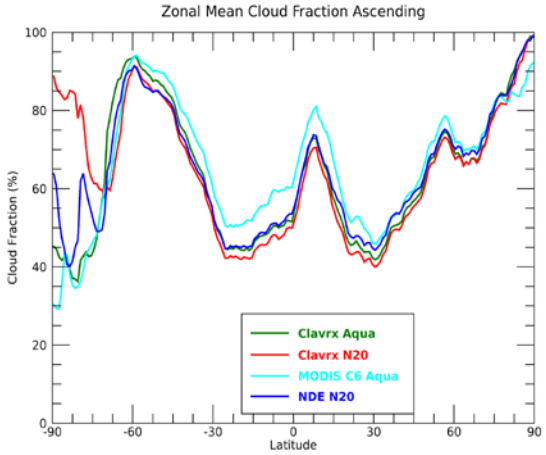

Zonal Mean Cloud Fraction Ascending
Cloud Fraction (%)
Latitude
NDE SNPP
MODIS C6 Aqua
NDE N20


Zonal Mean Cloud Fraction Descending
Cloud Fraction (%)
Latitude
NDE SNPP
MODIS C6 Aqua
NDE N20

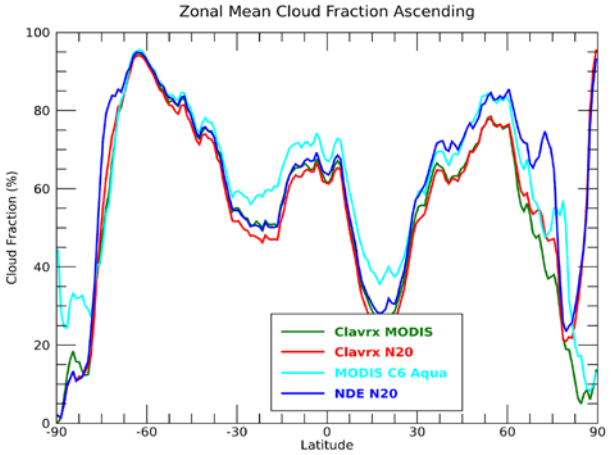
MODIS Comparison (Daytime)



Beta



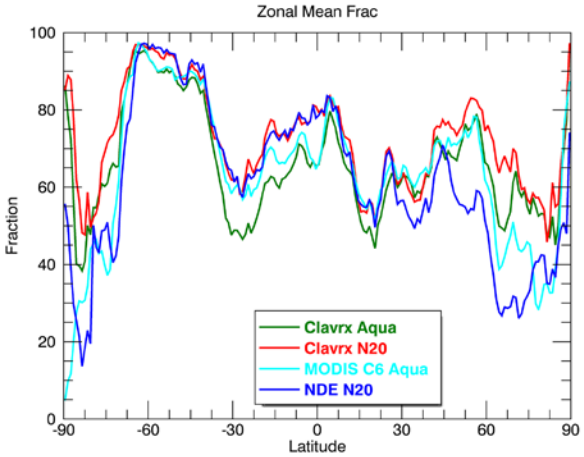
Provisional



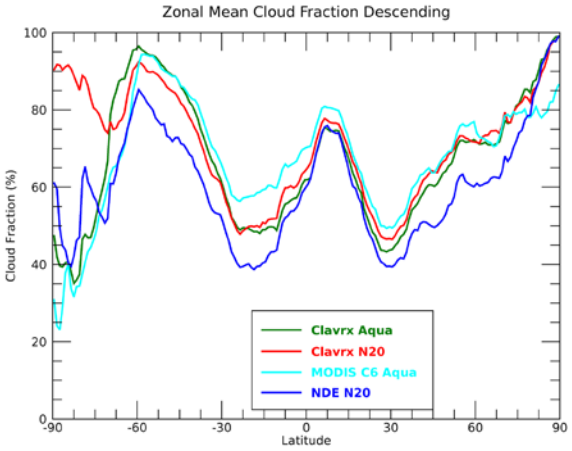
Full

- Beta (left image) was done in the Spring 2018 with less data so curves look differently.
- For Provisional (center image) and Full Validation (right image) NOAA-20 NDE in-line with NOAA-20 CLAVR-x (as expected).

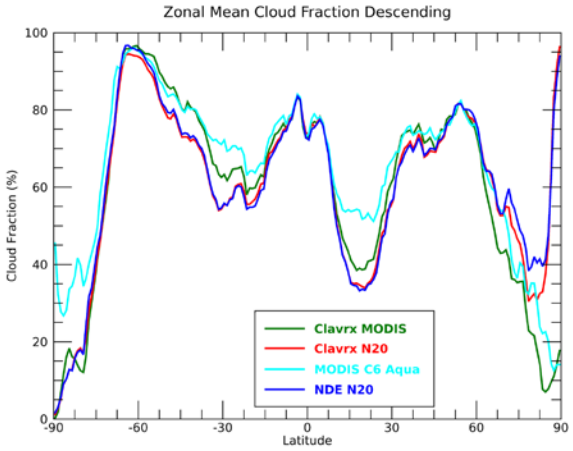
MODIS Comparison (Nighttime)



Beta



Provisional



Full

- Beta (left image) was done in the Spring 2018 with less data so curves look differently.
- For Provisional (center image) NOAA-20 NDE is relatively lower than NOAA-20 CLAVR-x. This was due to a bad LUT, which was replaced Nov 2018.
- For the Full Validation (right image) NOAA-20 NDE and CLAVR-x are in good agreement.

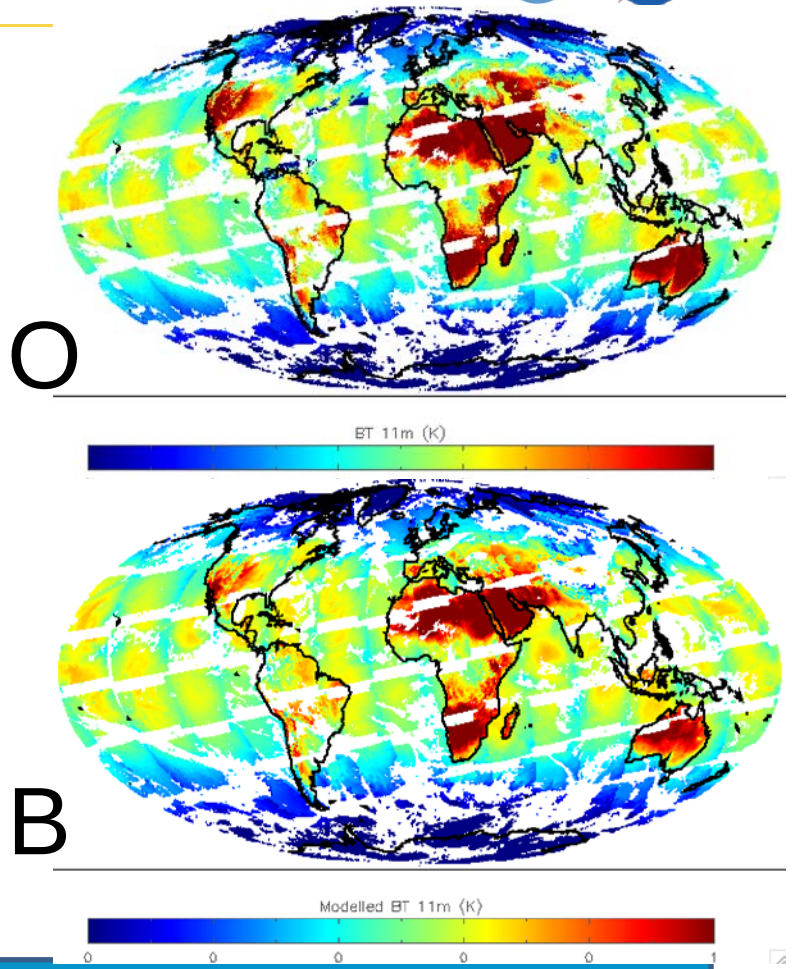
VIIRS All-Sky Radiance

Background

- GOES-16 All-Sky Radiance is the radiance product generated from GOES-16 IR channels for NWP Radiance Assimilation. Already used by ECMWF, monitored by NCEP
- This is similar to the VIIRS + CRIS radiance products but those aren't made yet for NOAA-20.
- NCEP has expressed interest in a VIIRS ASR product and that is what we are using to evaluate the ECM.
- This replaces our "SST" analysis as it more relevant to our users. (SST has it own mask)

Method

- We used 32x32 pixel arrays which results in grids with a similar spacing to GOES-16
- Require 10% of pixels to be clear to make a result
- We stored Mean and Mode of Clear Distribution - though only mean is used.
- CAVEATS: PFAAST and low-res GFS used.



VIIRS ASR over Ocean

- As we did with SST, we make O-B distribution and infer cloud mask performance
- ASR requires 10% clear pixels which automatically prevents some cloud contamination.
- As with SST, we see degradation at night relative to day. (same issue).
- We defined cold tail as pixels with O-B < mean peak -2 K.
- Performance is acceptable though spec for ASR is unknown