NOAA-20 VIIRS Enterprise Cloud Top Height (ACHA) Beta Maturity

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VIIRS Cloud Height Team

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Outline

- ACHA Description
- ACHA Status in NDE
- Evaluation of the ACHA
- Beta Maturity Conclusions
- Path Forward to Provisional
- Future Plans

STAR ECM Cal/Val Team

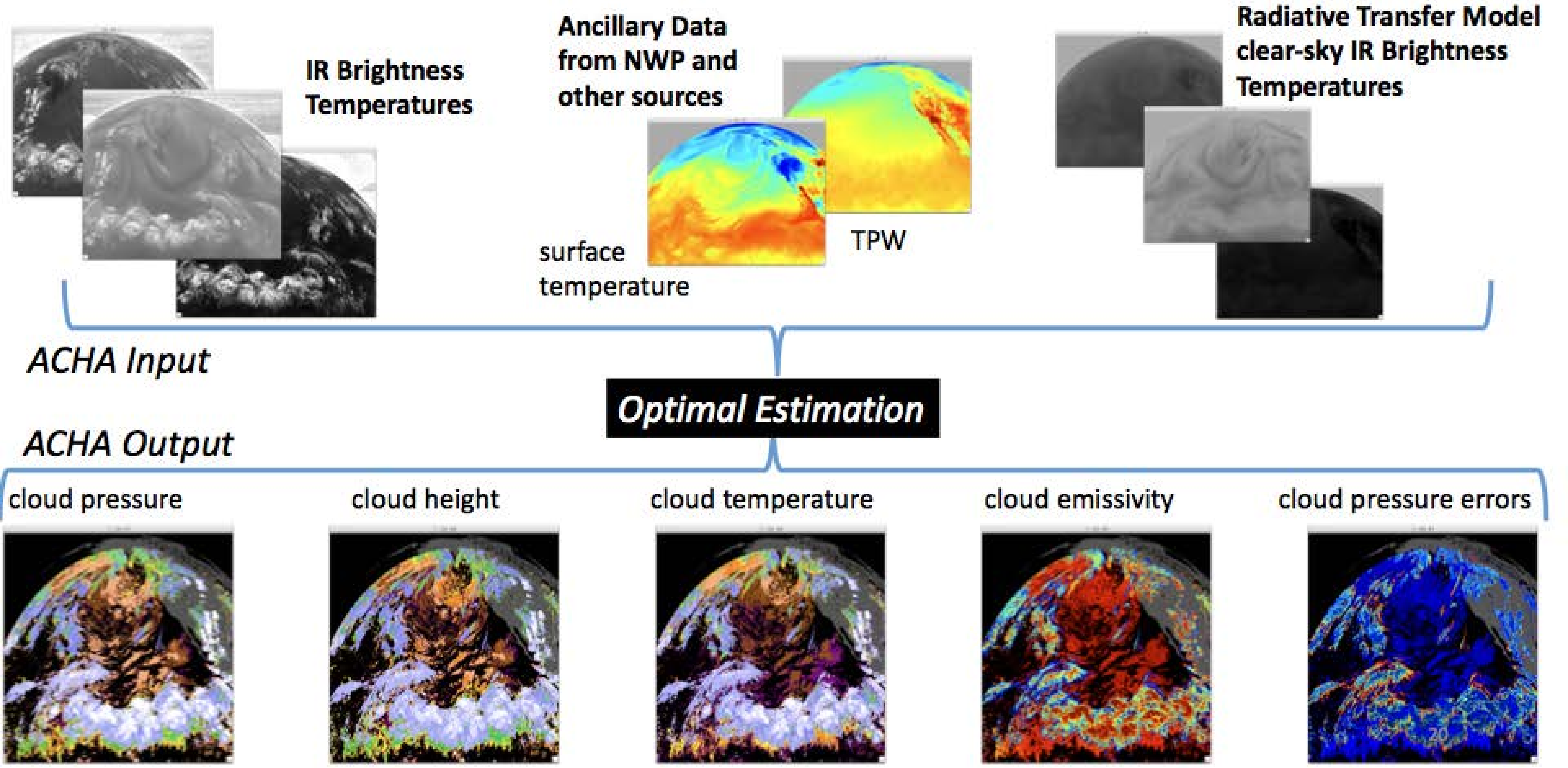
Name	Organization	Major Task
Andrew Heidinger	NESDIS/STAR	Cloud Team Lead
Yue Li	CIMSS	Algorithm development, verification
William Straka	CIMSS	ASSISTT integration
Steve Wanzong	CIMSS	Algorithm development
Shuang Qiu	OSPO	Product Area Lead

Enterprise Cloud Height Review

Enterprise Cloud Height

- ACHA estimates cloud top height using a combination of infrared channels
- Supports many sensors and it's part of the NOAA Enterprise Algorithm Suite.
- It is based on a 1-D var optimal estimation approach.
- The primary outputs are cloud top height, temperature and pressure.
- The demand for one algorithm to serve many sensors drove the ACHA development.

How AWG CLOUD HEIGHT (ACHA) Works

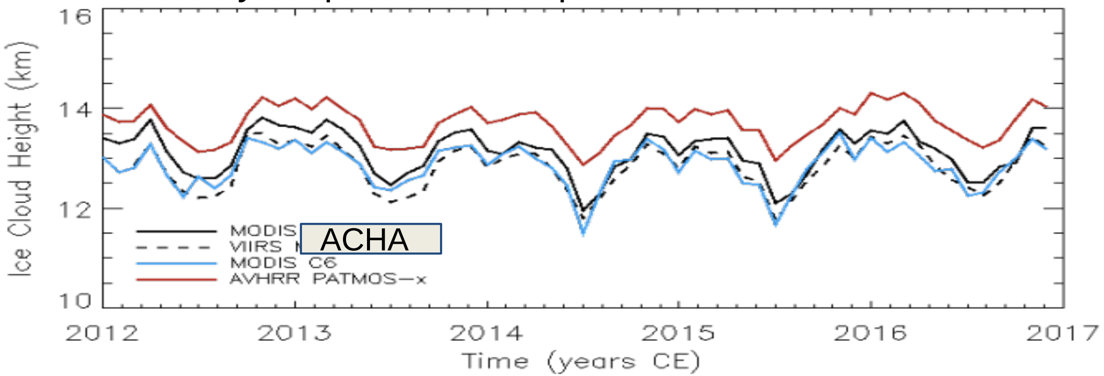


How to Use the Enterprise Cloud Height

- The fundamental output of ACHA is cloud top temperature
- Cloud top height and pressure are derived using NWP profiles
- Due to the nature of IR radiative transfer, the retrieved cloud top height are typically lower than the true top height

ACHA Heritage

- ACHA has run for years on AVHRR, GOES in OSPO and other sensors in STAR.
- PATMOS-x is a NOAA Climate Program that uses NOAA Enterprise algorithms to make climate records.
- The figure below show the NOAA Enterprise applied to Brazil for the entire AQUA/MODIS record.
- Shows the nice stability in spatial and temporal variation.



ACHA Channels

- ACHA uses three IR channels for VIIRS
  - M14
  - M15
  - M16
- ACHA also supports other channels combinations, a.k.a. modes. For VIIRS, M15 and M16 only is also supported.

		Band No.	Driving EDR(s)	Spectral Range (um)	Horiz Sample Interval (km) (track x Scan) Nadir	End of Scan
Reflective Bands	VisNIR	M1	Ocean Color Aerosol	0.402 - 0.422	0.742 x 0.259	1.60 x 1.58
		M2	Ocean Color Aerosol	0.436 - 0.454	0.742 x 0.259	1.60 x 1.58
		M3	Ocean Color Aerosol	0.478 - 0.498	0.742 x 0.259	1.60 x 1.58
		M4	Ocean Color Aerosol	0.545 - 0.565	0.742 x 0.259	1.60 x 1.58
		I1	Imagery EDR	0.600 - 0.680	0.371 x 0.387	0.80 x 0.789
		M5	Ocean Color Aerosol	0.662 - 0.682	0.742 x 0.259	1.60 x 1.58
		M6	Atmosph. Correct.	0.739 - 0.754	0.742 x 0.776	1.60 x 1.58
		I2	NDVI	0.846 - 0.885	0.371 x 0.387	0.80 x 0.789
		M7	Ocean Color Aerosol	0.846 - 0.885	0.742 x 0.259	1.60 x 1.58
	S/MWIR	M8	Cloud Particle Size	1.230 - 1.250	0.742 x 0.776	1.60 x 1.58
		M9	Cirrius/Cloud Cover	1.371 - 1.386	0.742 x 0.776	1.60 x 1.58
		I3	Binary Snow Map	1.580 - 1.640	0.371 x 0.387	0.80 x 0.789
		M10	Snow Fraction	1.580 - 1.640	0.742 x 0.776	1.60 x 1.58
		M11	Clouds	2.225 - 2.275	0.742 x 0.776	1.60 x 1.58
Emissive Bands		I4	Imagery Clouds	3.550 - 3.930	0.371 x 0.387	0.80 x 0.789
		M12	SST	3.660 - 3.840	0.742 x 0.776	1.60 x 1.58
		M13	SST Fires	3.973 - 4.128	0.742 x 0.259	1.60 x 1.58
	LWIR	M14	Cloud Top Properties	8.400 - 8.700	0.742 x 0.776	1.60 x 1.58
		M15	SST	10.263 - 11.263	0.742 x 0.776	1.60 x 1.58
		I5	Cloud Imagery	10.500 - 12.400	0.371 x 0.387	0.80 x 0.789
		M16	SST	11.538 - 12.488	0.742 x 0.776	1.60 x 1.58

NDE/STAR VIIRS ACHA Production Status

Algorithm	Suomi NPP	NOAA-20
April 2017 and January 2018 DAP January 2018 DAP contains code to run both NPP and N20	NDE February 23, 2018	NDE Currently in I&T (Data available since 28 March, 2018)
February 2018 Science Code delivery	STAR Systematic production since June, 2018 NDE (Estimated Delivery in Aug 2018)	STAR Systematic production since June, 2018 NDE (Estimated Delivery in Aug 2018)

Users of ACHA

- Downstream Enterprise Algorithms, including DCOMP, NCOMP and cloud base algorithms
- VIIRS Polar Winds.
- NUCAPS
- ESRL
- Potentially External ACHA Users: NWP data assimilation teams

Enterprise Cloud Height NDE Status

ACHA Deliveries

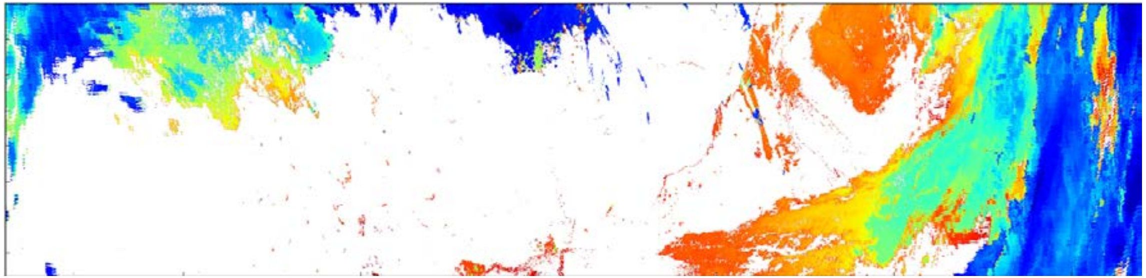
- Current Operational Version (NPP-only)
  - April 2017 DAP
- Current I&T Version
  - January 2018 DAP
- February 2018 science code delivery
  - Estimated DAP delivery to NDE in August 2018

ACHA v1r2 Integration Results

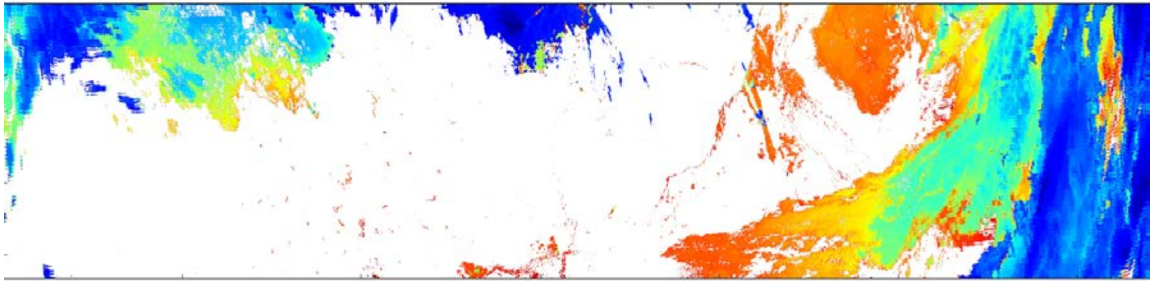
- Analysis was performed using GLANCE (which is used for algorithm integration verification) with an epsilon of 0 (i.e. a perfect match).
    - Small differences are to be expected due to slight run to run rounding differences.

- Due an issue discovered in ECM beta, which was fixed within NDE in mid-June, a verification test was performed using that data being run at NDE against locally run SAPF data to ensure that the code was integrated and being run correctly. The four scenes that were compared were chosen due to them being the NDE validation "golden" granules
    - 0045Z on 8 April, 2018 (NOAA-20)
    - 0749Z on 8 April, 2018 (NOAA-20) - **shown**
    - 1743Z on 16 Dec, 2016 (SNPP)
    - 0659Z on 8 April 2018 (NOAA-20)

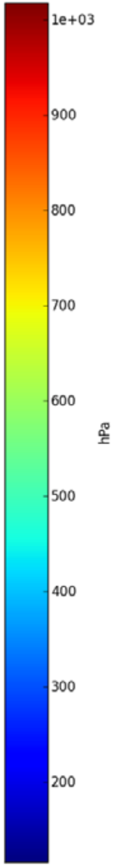
ACHA v1r2 Integration Results (CTP)



CIMSS SAPF



NDE SAPF



ACHA (CTP) v1r2 Integration Results

- Correlation between NDE and CIMSS SAPF run : 0.996

- Mean difference : -0.01910

- Other products and scenes show similar results

- As mentioned previously, it is expected that there will be differences due to machine and run to run differences, and minor differences (as seen) are as expected.

Evaluation of the NDE ACHA

Requirements Cloud Top Height (1)

- JERD-2428 The algorithm shall produce a cloud height product that has a horizontal cell size of 0.8 km at Nadir.

- JERD-2474 The algorithm shall produce a cloud height product that has a vertical reporting interval of top and base of highest cloud in the column.

- JERD-2475 The algorithm shall produce a cloud height product that has a mapping uncertainty, (3 sigma) of 4 km.

Requirements Cloud Top Height (2)

- JERD-2476 The algorithm shall produce a cloud top height product that has a measurement precision of
  - 1 km for COT >=1 and 2.0km for COT < 1

- JERD-2477 The algorithm shall produce a cloud top height product that has a measurement accuracy of
  - 1km for COT >=1 and 2.0km for COT < 1

Requirements Cloud Top Pressure (1)

- JERD-2428 The algorithm shall produce a cloud top pressure product that has a horizontal cell size of 0.8 km at Nadir.
- JERD-2492 The algorithm shall produce a cloud top pressure product that has a vertical reporting interval of tops of up to four layers.
- JERD-2493 The algorithm shall produce a cloud top pressure product that has a mapping uncertainty, (3 sigma) of 4 km.

Requirements Cloud Top Pressure (2)

- JERD-2494 The algorithm shall produce a cloud top pressure product that has a measurement precision of
  - 100hPa for COT >=1 and 200hPa for COT < 1

- JERD-2495 The algorithm shall produce a cloud top pressureproduct that has a measurement accuracy of
  - 100hPa for COT >=1 and 200hPa for COT < 1

Requirements Cloud Top Temperature (1)

- JERD-2434 The algorithm shall produce a cloud top temperature product that has a horizontal cell size of 0.8 km at Nadir.
- JERD-2496 The algorithm shall produce a cloud top temperature product that has a vertical reporting interval of tops of up to four layers.
- JERD-2497 The algorithm shall produce a cloud top temperature product that has a mapping uncertainty, (3 sigma) of 4 km.

Requirements Cloud Top Temperature (2)

- JERD-2498 The algorithm shall produce a cloud top temperature product that has a measurement precision of
  - 6K for COT >=1 and 12K for COT < 1

- JERD-2499 The algorithm shall produce a cloud top temperature product that has a measurement accuracy of
  - 6K for COT >=1 and 12K for COT < 1

JPSS Data Products Maturity Definition

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.

Evaluation Methodology

We have chosen independent sources of cloud height products that provide qualitative and quantitative analysis of the performance.

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

Our Specific Evaluation Methodology applied here:

1. Visual inspection of NDE ACHA against CLAVR-x ACHA

1. Validation against NASA CALIPSO/CALIOP

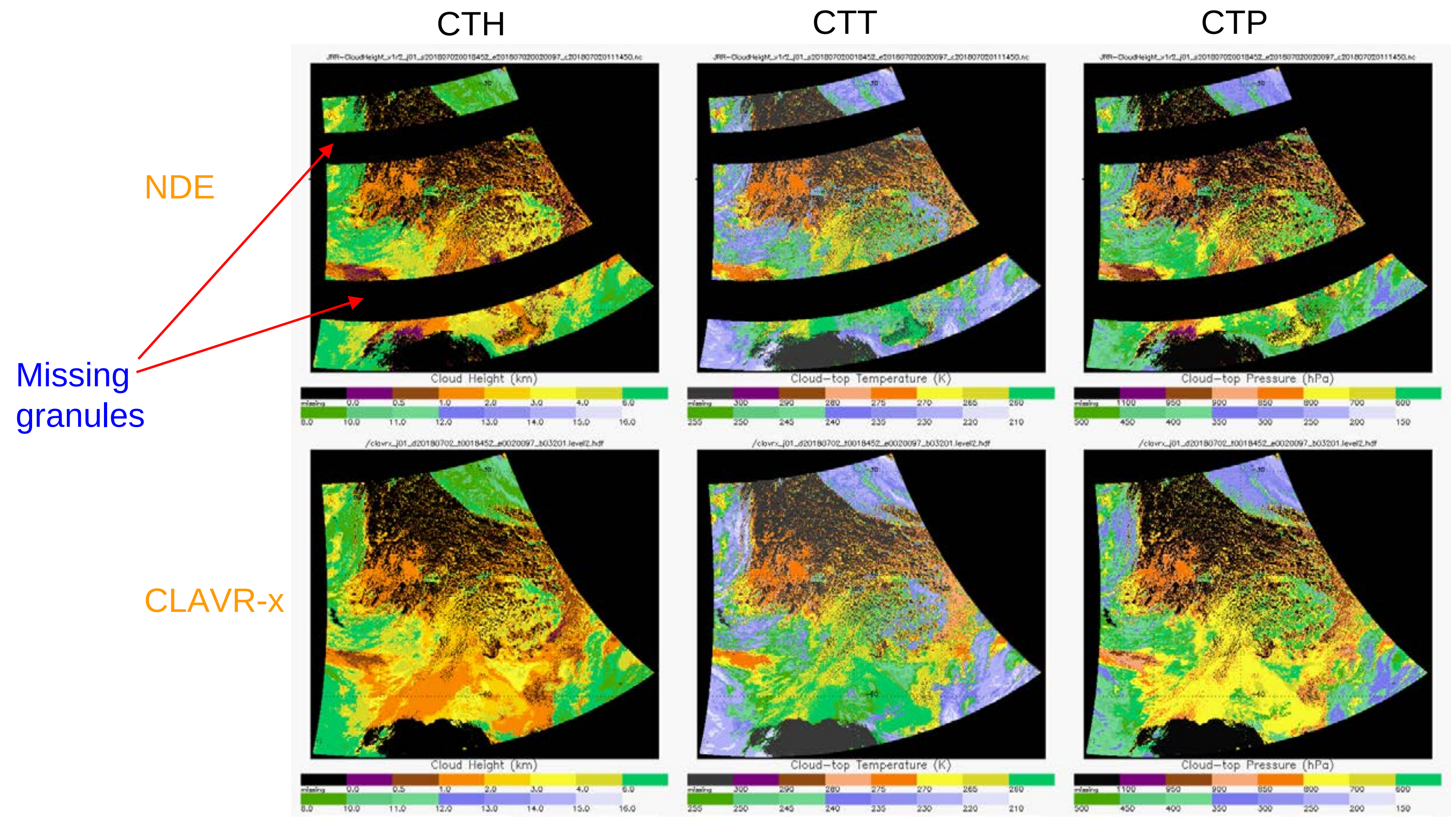
1. Validation against NASA MODIS MYD06

Data Used in this Analysis

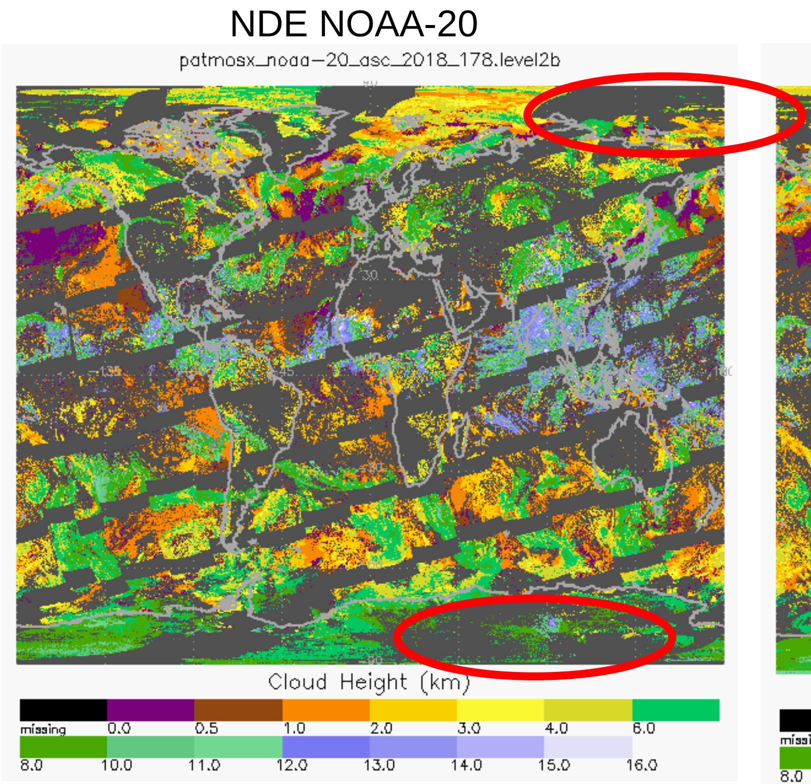
- NOAA-20 NDE v1r2 from 15 days in June and July, 2018
- NOAA-20 CLAVR-x from 15 days in June and July, 2018.
- NASA AQUA/MODIS from 10 days in June, 2018.
- NASA CALIPSO from 15 days in June and July, 2018.

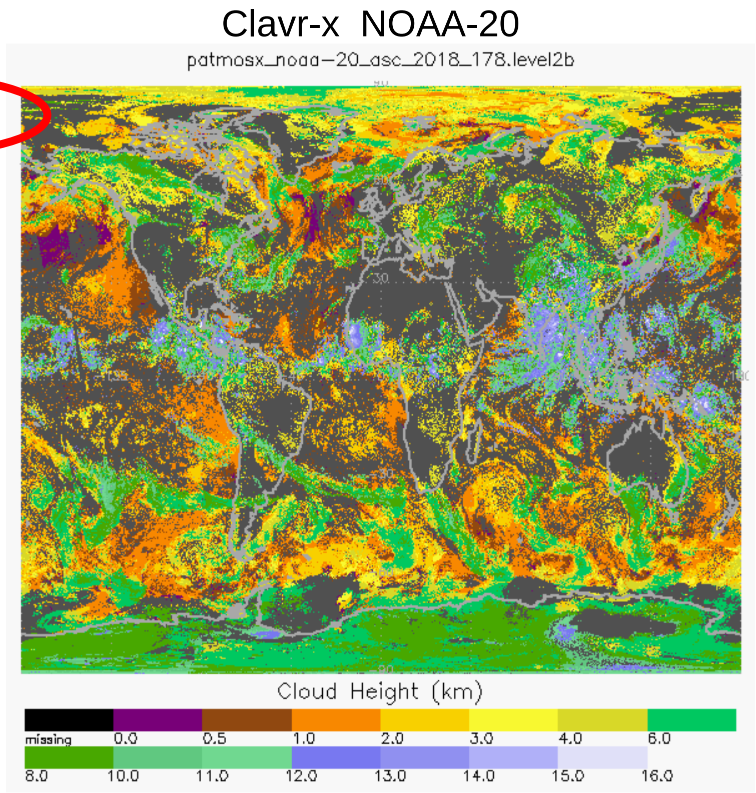
Visual Comparisons with CLAVR-x ACHA

Level 2 Comparison



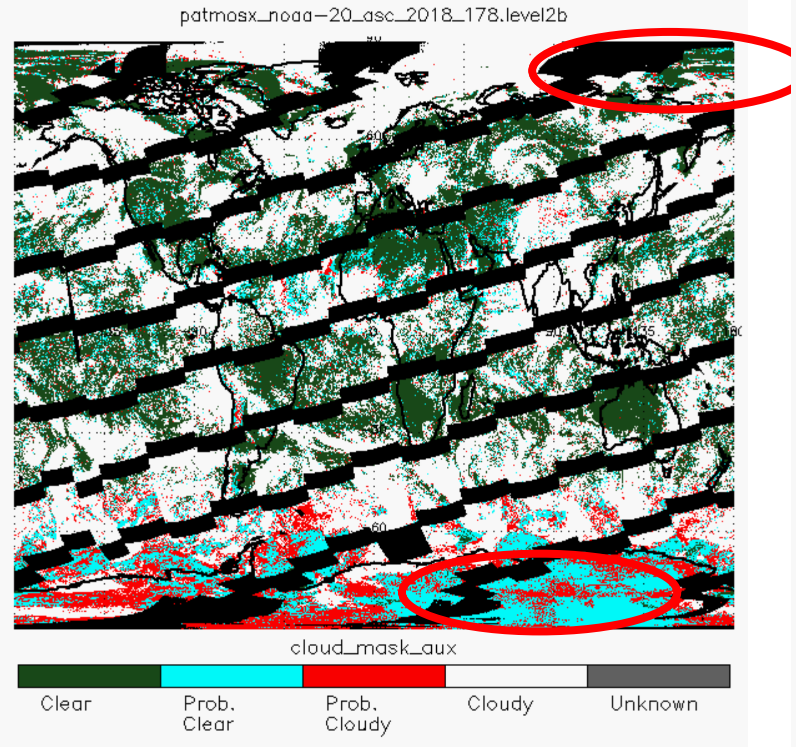
Cloud Height Ascending Node



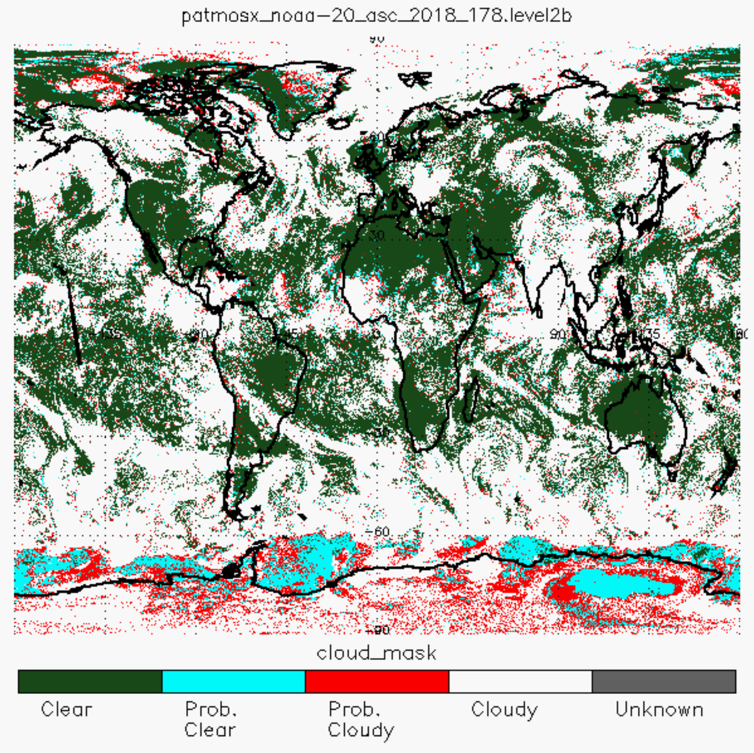


Cloud Mask Ascending Node

NDE NOAA-20



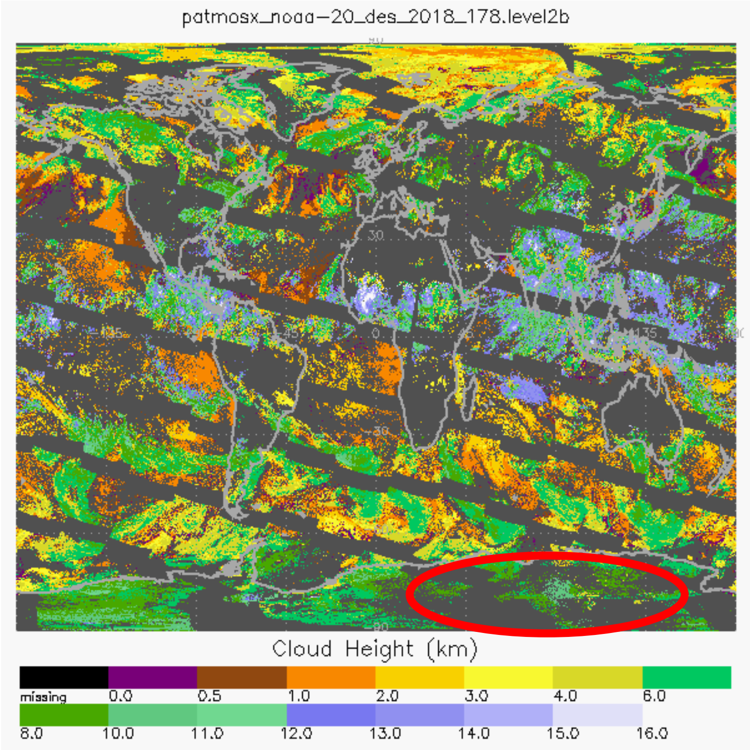
Clavr-x NOAA-20



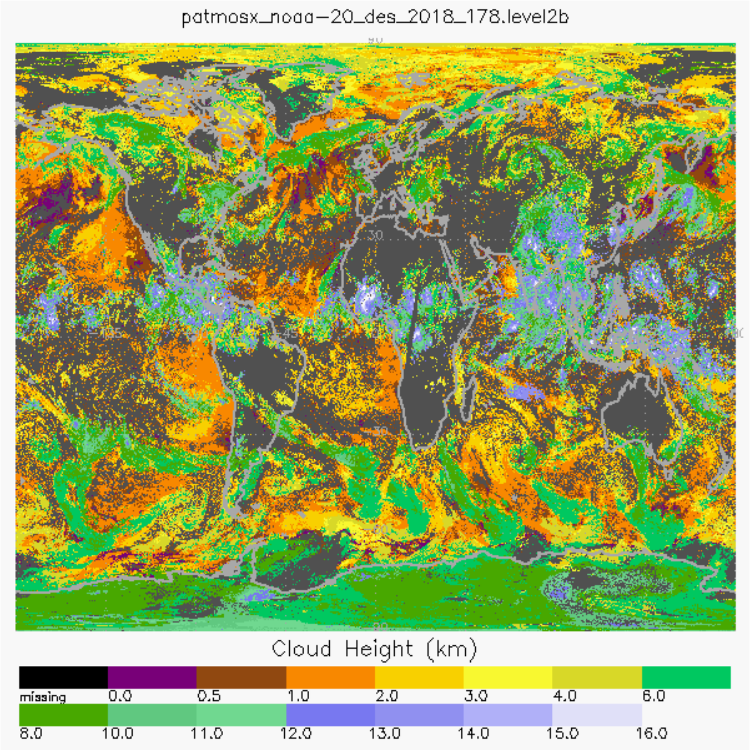
Less data coverage in ACHA NDE can be attributed to both missing data and missing cloud detection

Cloud Height Descending Node

NDE NOAA-20

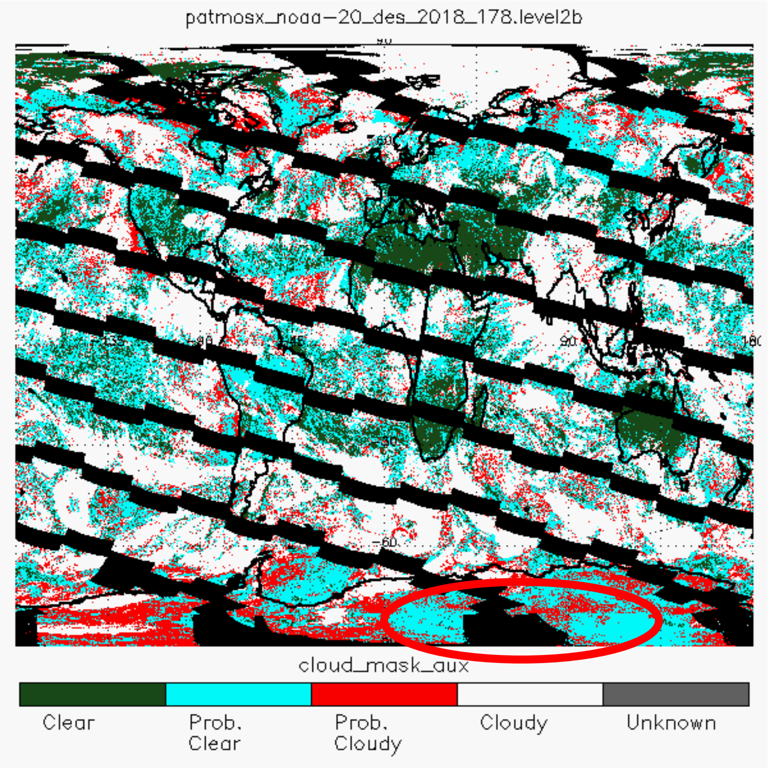


Clavr-x NOAA-20

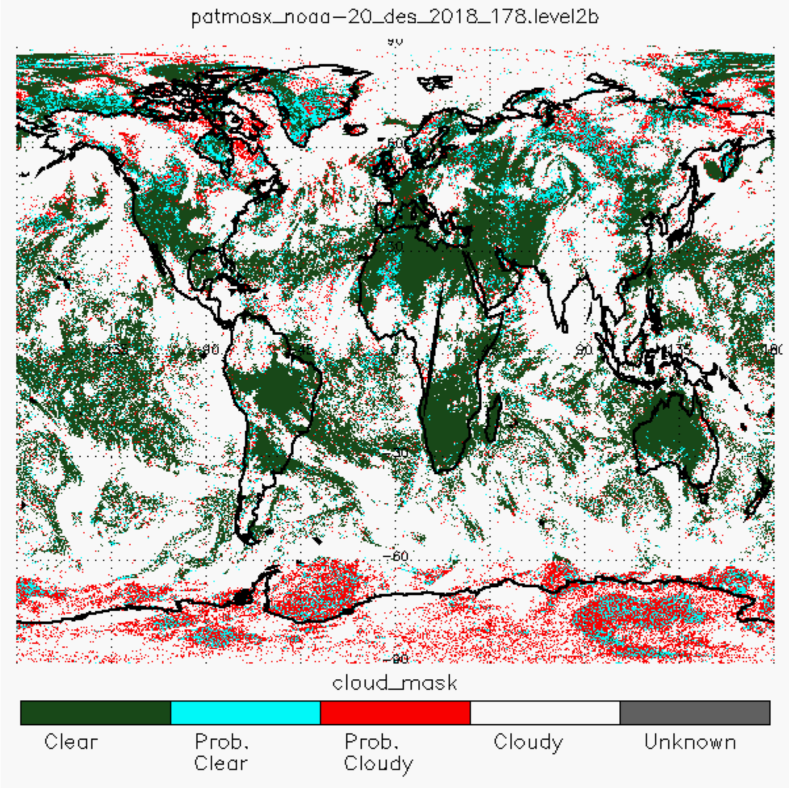


Cloud Mask Descending Node

NDE NOAA-20

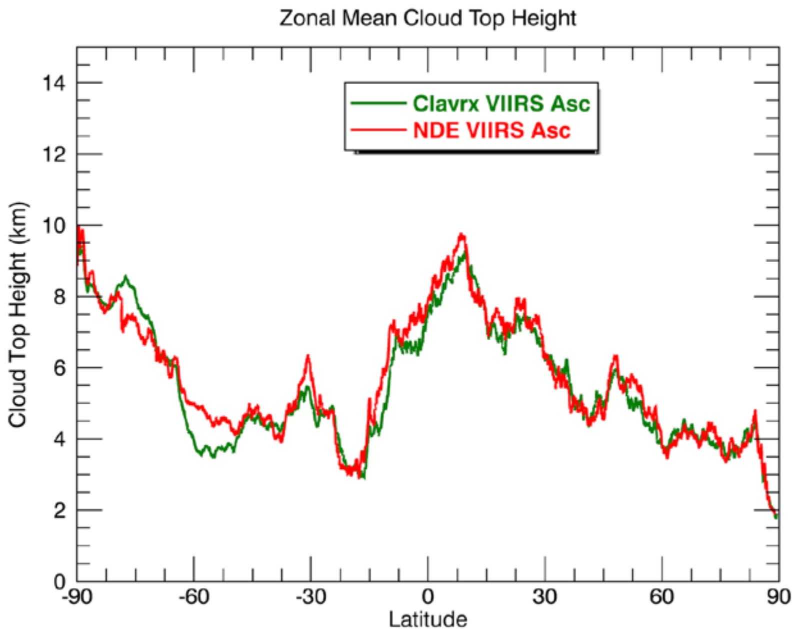


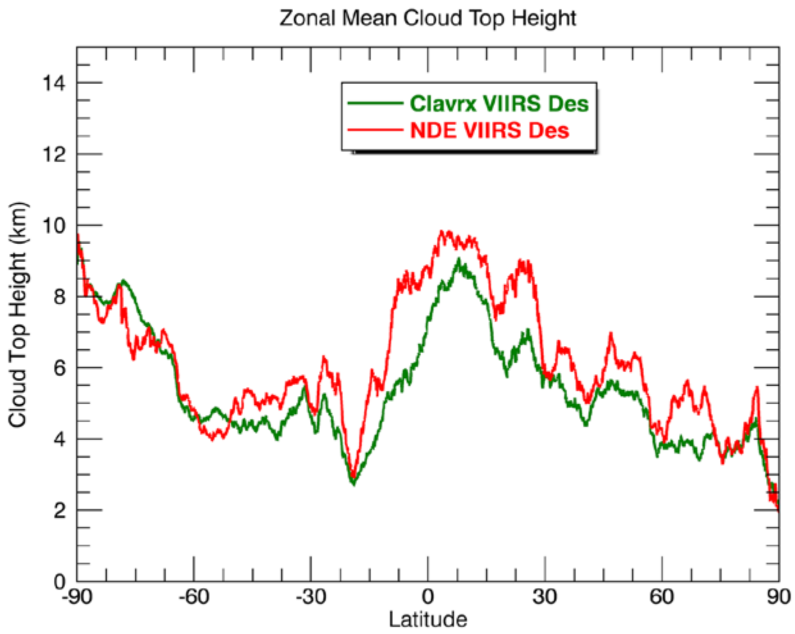
Clavr-x NOAA-20



Less data coverage in ACHA NDE can be attributed to both missing data and missing cloud detection

Global Zonal Mean





- Zonal plots computed from 15 days of ACHA products from NDE and Clavr-x
- Further investigation is needed to find out why descending track shows larger differences

Bad values

- A number of granules show unrealistic cloud height and pressure values. For example, we see cloud height greater than 1,000,000 meter and cloud pressure greater than 35,000 hPa. There are also negative values for both cloud height and pressure. However, the cloud temperature for those pixels are reasonable.
- This is mostly likely due to bad NWP profiles as cloud temperature is retrieved first and height and pressure are derived using NWP profiles.
- A constraint has been added to ACHA to fix this issue.

Conclusions from Visual Comparisons

Issue	Comment
Less retrievals in Polar	This is partially a cloud mask issue
Missing granules	This is a PDA issue and will be resolved in the June 2018 DAP (will be in Ops ~end 2018).
Bad cloud height and pressure values	This is likely due to NWP profiles

Comparison to CALIPSO/CALIOP

- Data: 15 days of ACHA data from NDE and CLAVR-x in 2018
- Combined five and one km matchup files with Calipso
- Additional filtering including phase matching and single layer were implemented to account for different phase algorithms

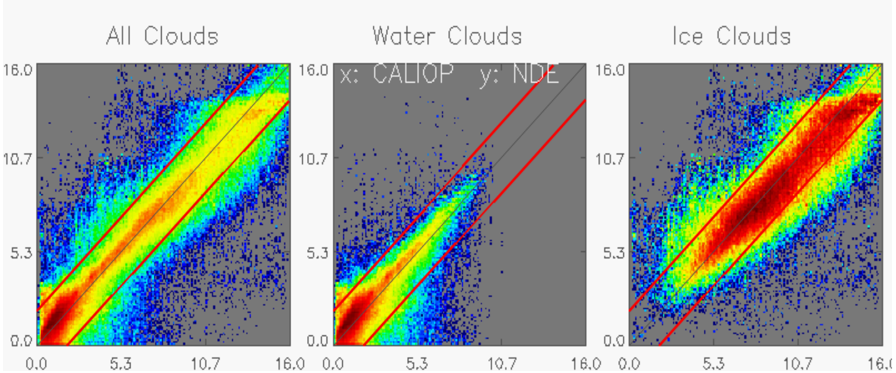
Specs requirement for Cloud Top Products

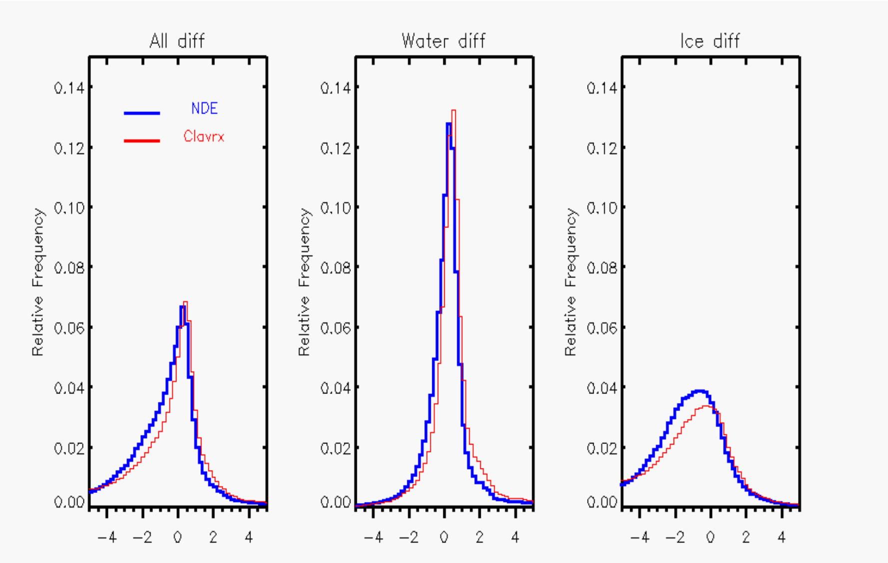
- CTT = Cloud-top Temperature
- CTH = Cloud-top Height
- CTP = Cloud-top Pressure

Attributes	**L1RD Threshold (accuracy = precision)**
CTT	3K when $\tau \geq 1$, 6K when $\tau < 1$
CTH	1km when $\tau \geq 1$, 2km when $\tau < 1$
CTP	$\tau \geq 1$: 100mb for [0,3km], 75mb for [3,7km], 50mb for > 7km

No filtering - CTH

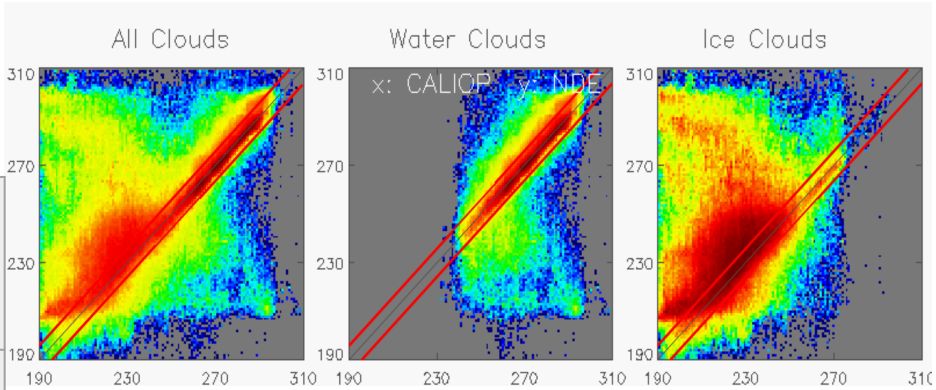
	Unit (km)	NDE	Clavrx	Meet Specs-NDE	Meet Specs -Clavrx
All Clouds	Bias	-1.2	-1.5	55.3%	51.6%
	Std Dev	3.1	3.6	39.0%	28.0%
Water Clouds	Bias	0.3	0.5	75.6%	72.1%
	Std Dev	1.7	1.5	74.5%	74.4%
Ice Clouds	Bias	-2.2	-2.6	43.0%	39.3%
	Std Dev	3.4	4.0	38.8%	25.8%

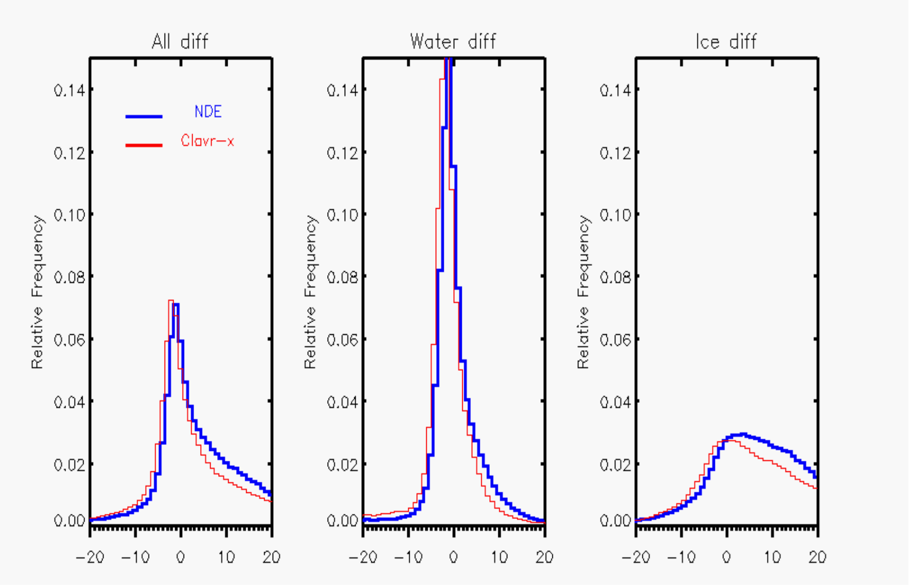




No filtering - CTT

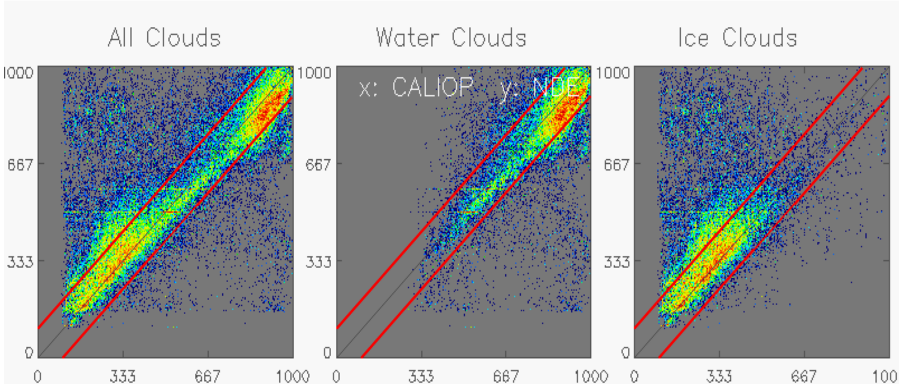
	Unit (K)	NDE	Clavrx	Meet Specs-NDE	Meet Specs -Clavrx
All Clouds	Bias	9.9	11.2	35.2%	34.4%
	Std Dev	21.3	24.0	16.5%	11.1%
Water Clouds	Bias	-1.2	-2.1	60.4%	57.8%
	Std Dev	10.5	8.0	62.3%	65.1%
Ice Clouds	Bias	16.4	19.1	20.4%	20.7%
	Std Dev	23.2	26.7	16.5%	10.0%

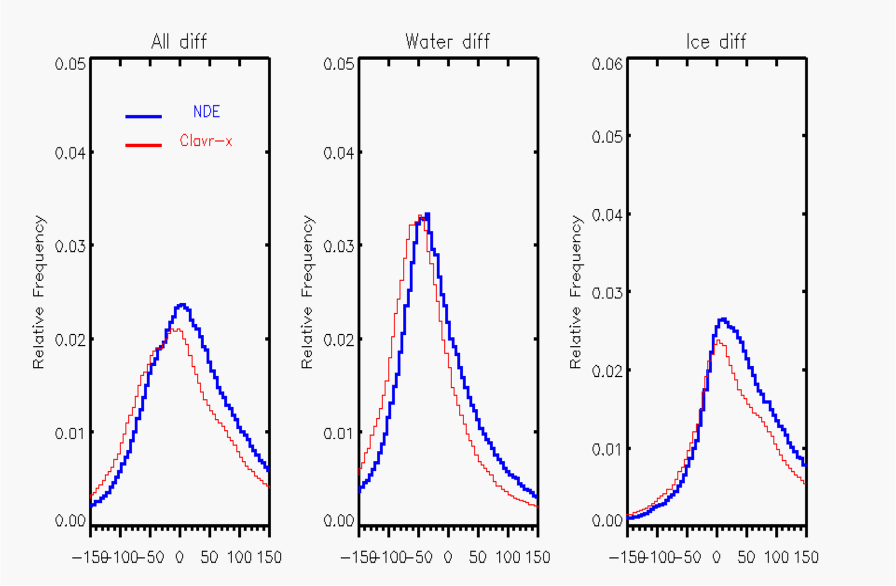




No filtering - CTP

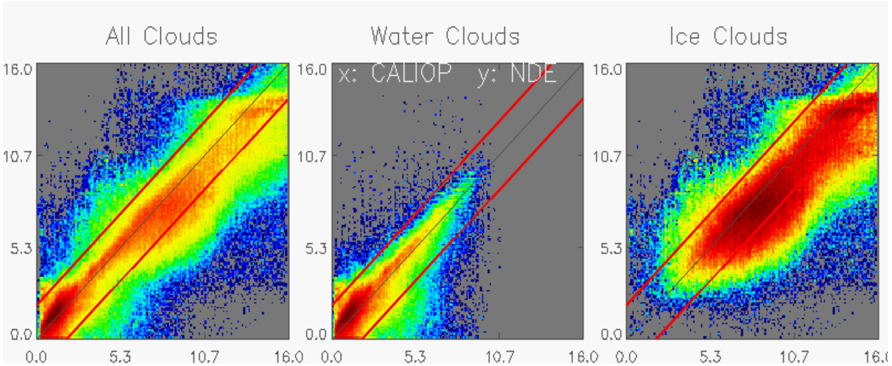
	Unit (hPa)	NDE	Clavrx	Meet Specs-NDE	Meet Specs -Clavrx
All Clouds	Bias	44.3	40.5	57.2%	54.2%
	Std Dev	169.3	190.8	49.9%	42.5%
Water Clouds	Bias	-35.1	-59.5	73.8%	68.0%
	Std Dev	123.1	112.2	74.6%	73.9%
Ice Clouds	Bias	109.7	126.2	43.5%	42.3%
	Std Dev	174.1	202.3	28.3%	19.2%

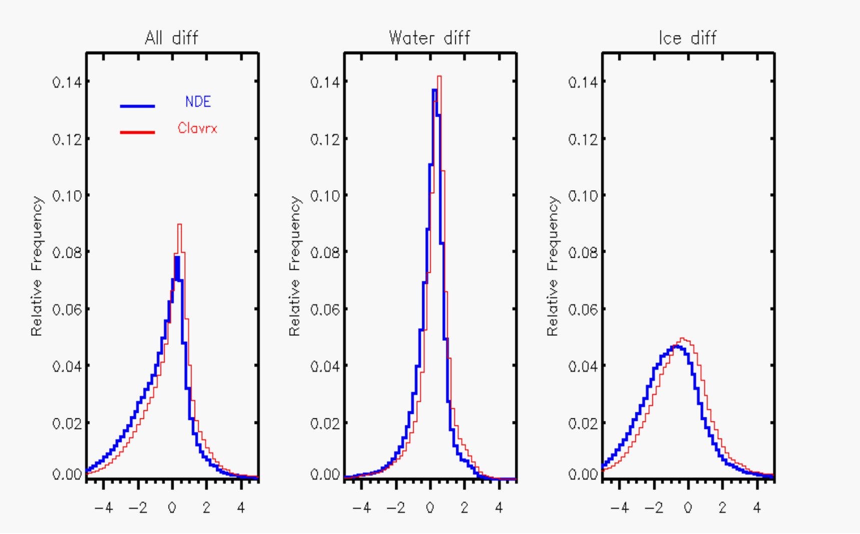




Phase matched - CTH

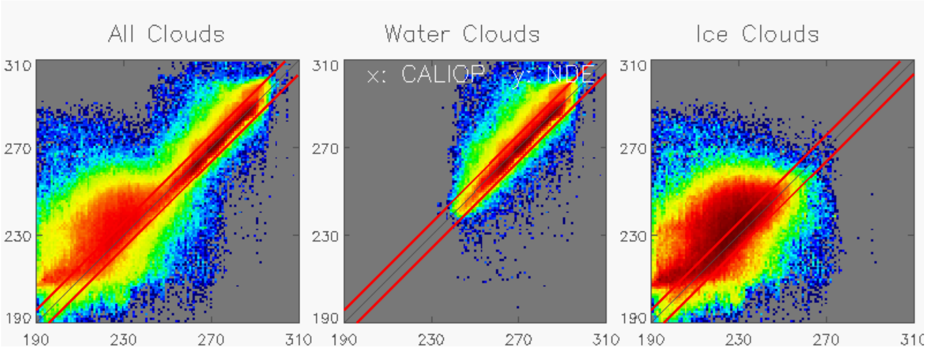
	Unit (km)	NDE	Clavrx	Meet Specs-NDE	Meet Specs -Clavrx
All Clouds	Bias	-0.6	-0.1	63.4%	66.4%
	Std Dev	1.7	1.5	58.3%	65.2%
Water Clouds	Bias	-0.01	0.2	80.3%	77.4%
	Std Dev	1.1	1.1	80.3%	79.9%
Ice Clouds	Bias	-1.0	-0.5	51.5%	57.0%
	Std Dev	1.9	1.8	54.9%	57.1%

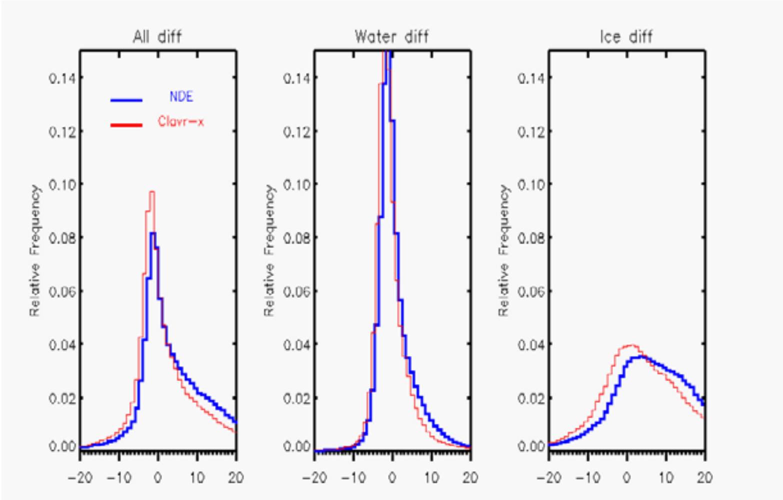




Phase matched - CTT

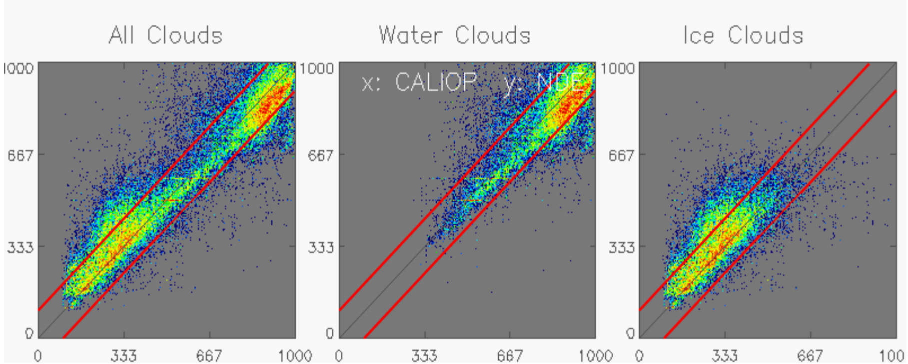
	Unit (K)	NDE	Clavrx	Meet Specs-NDE	Meet Specs -Clavrx
All Clouds	Bias	5.5	2.4	40.7%	45.0%
	Std Dev	11.5	10.1	24.0%	30.9%
Water Clouds	Bias	0.8	-0.5	64.8%	63.1%
	Std Dev	5.5	4.9	58.7%	67.4%
Ice Clouds	Bias	8.7	4.9	24.1%	29.9%
	Std Dev	13.4	12.4	26.6%	28.1%

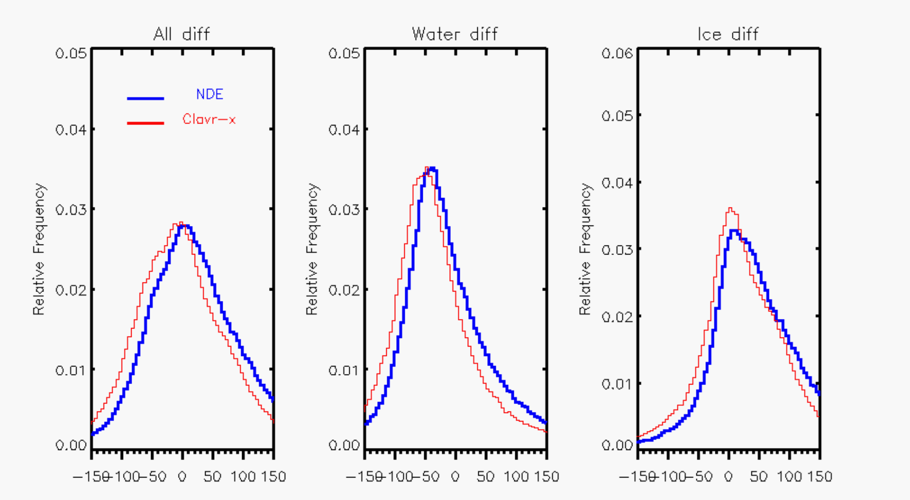




Phase matched - CTP

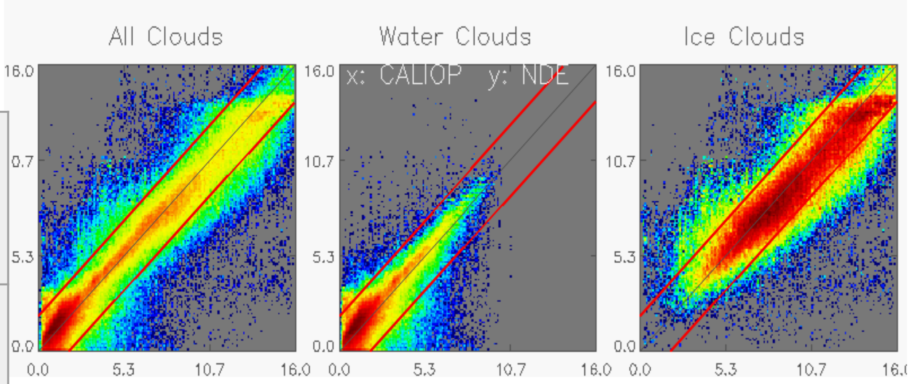
	Unit (hPa)	NDE	Clavrx	Meet Specs-NDE	Meet Specs -Clavrx
All Clouds	Bias	14.5	-15.2	65.5%	67.1%
	Std Dev	92.5	89.1	65.5%	67.6%
Water Clouds	Bias	-17.4	-42.9	78.0%	73.1%
	Std Dev	90.4	91.4	79.4%	79.0%
Ice Clouds	Bias	46.2	18.1	52.9%	59.9%
	Std Dev	83.2	73.6	54.8%	61.4%

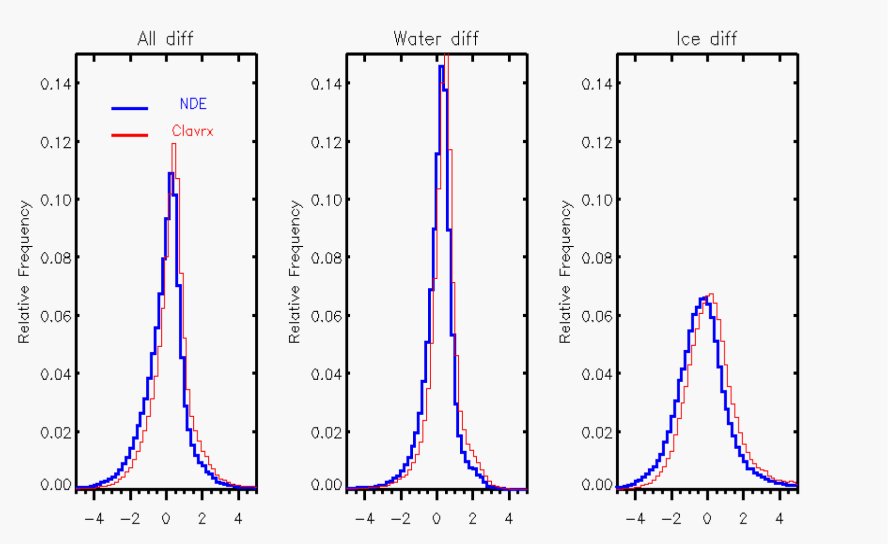




Phase matched and Single Layer only - CTH

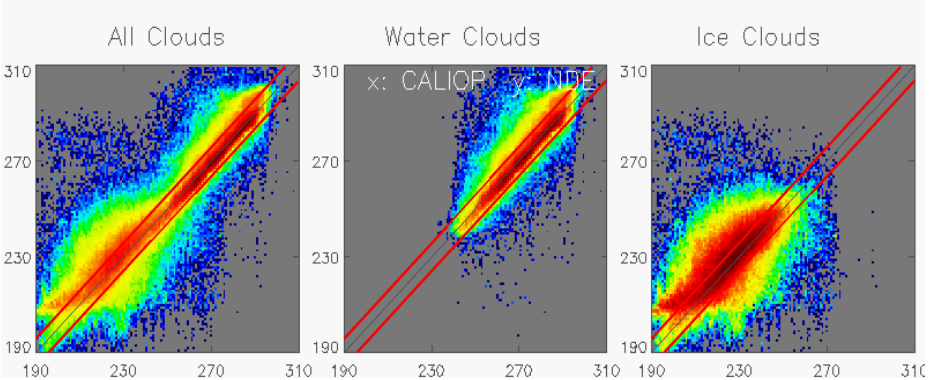
	Unit (km)	NDE	Clavrx	Meet Specs-NDE	Meet Specs -Clavrx
All Clouds	Bias	-0.05	0.3	77.4%	75.4%
	Std Dev	1.3	1.2	77.3%	77.6%
Water Clouds	Bias	0.1	0.3	82.8%	79.2%
	Std Dev	0.9	0.9	83.1%	82.7%
Ice Clouds	Bias	-0.3	0.2	69.8%	69.4%
	Std Dev	1.6	1.5	70.4%	69.6%

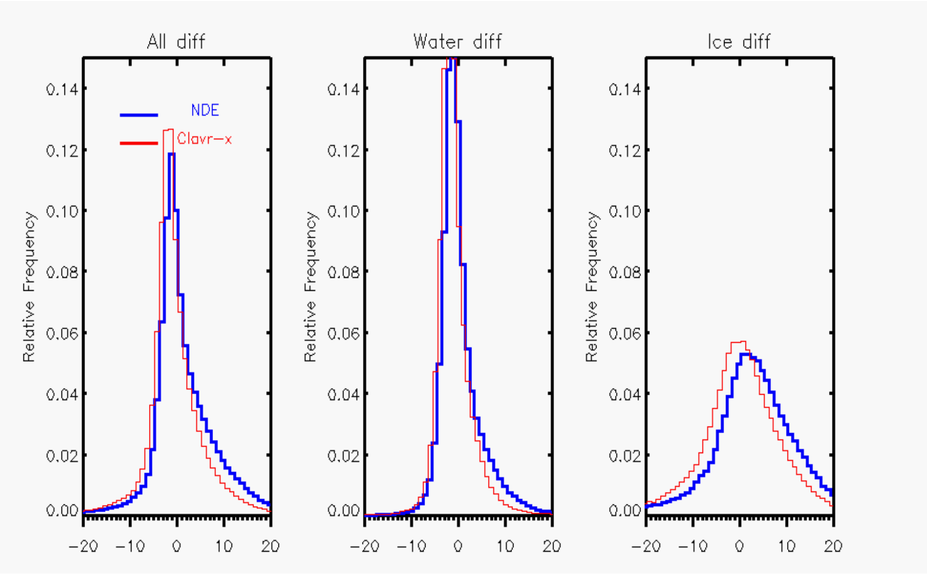




Phase matched and Single Layer only - CTT

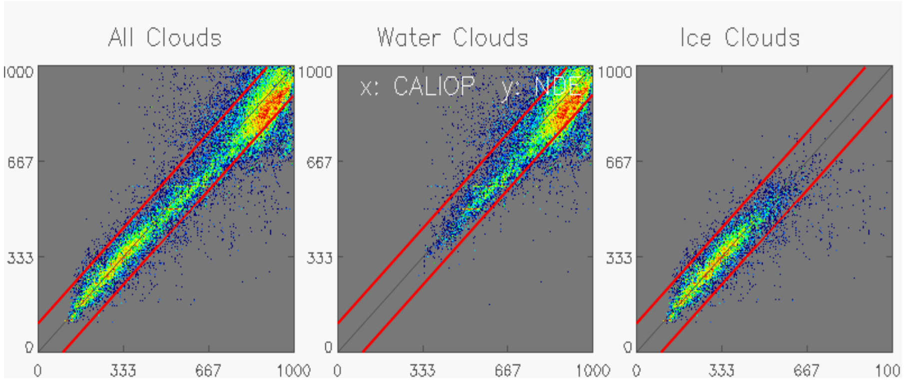
	Unit (K)	NDE	Clavrx	Meet Specs-NDE	Meet Specs -Clavrx
All Clouds	Bias	1.7	-0.6	53.9%	55.5%
	Std Dev	8.0	6.7	44.6%	58.8%
Water Clouds	Bias	0.4	-1.0	66.9%	64.7%
	Std Dev	5.0	4.2	64.1%	72.5%
Ice Clouds	Bias	3.5	-0.003	36.1%	40.7%
	Std Dev	10.7	9.3	38.4%	40.7%

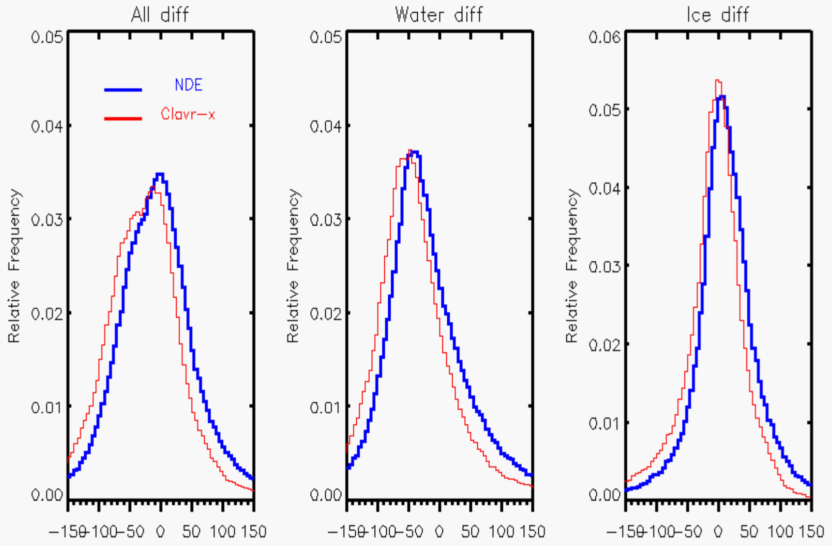




Phase matched and Single Layer only - CTP

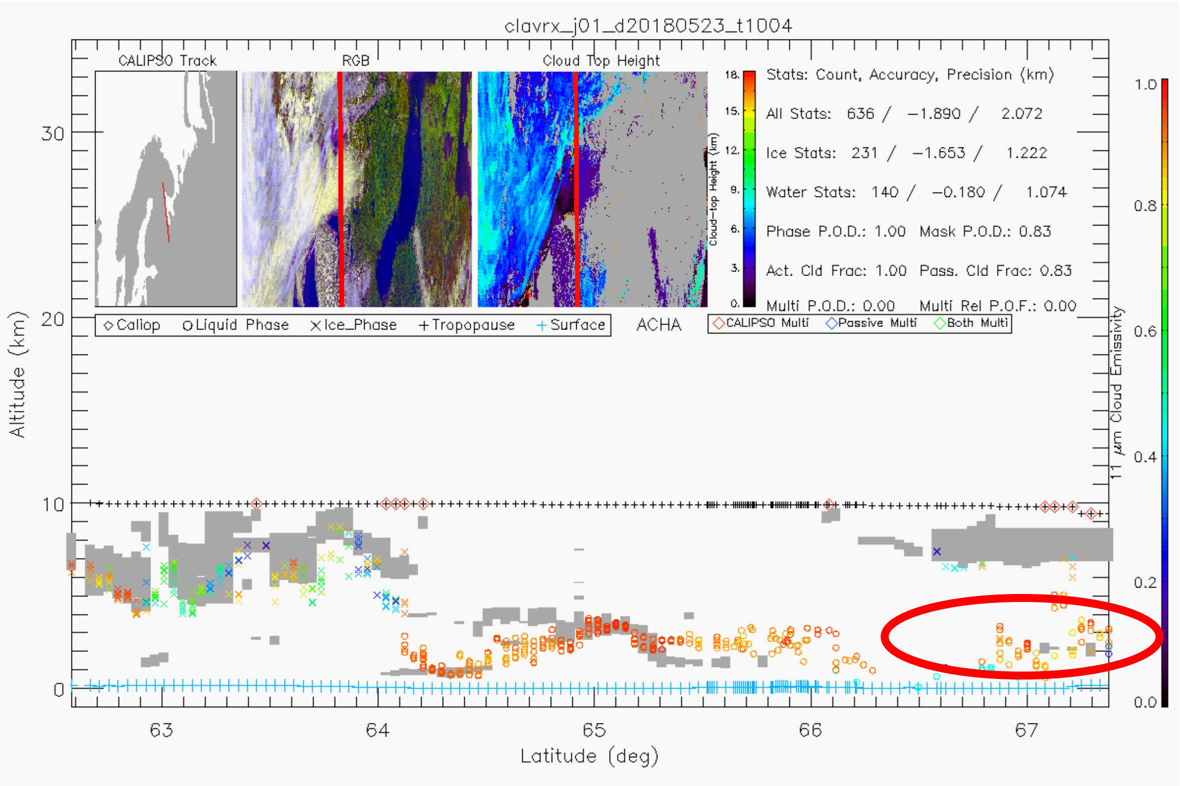
	Unit (hPa)	NDE	Clavrx	Meet Specs-NDE	Meet Specs -Clavrx
All Clouds	Bias	-18.1	-43.1	80.7%	76.6%
	Std Dev	76.8	77.7	80.4%	77.5%
Water Clouds	Bias	-26.4	-53.3	80.1%	74.3%
	Std Dev	82.8	82.4	82.0%	81.7%
Ice Clouds	Bias	0.2	-18.6	82.1%	82.2%
	Std Dev	57.3	58.1	82.1%	81.6%





Polar region

- Figure on the right shows an example comparing ACHA and CALIPSO over the Arctic
- When phase is correct, ACHA retrieval performs as expected
- Incorrect phase negatively affects first guess in ACHA's OE algorithm and its retrieval capability



Evaluation of Arctic Cloud Top height

	Unit (km)	NDE - Global	NDE - Arctic	Meet Specs- Global	Meet Specs -Arctic
No filter	Bias	-1.2	-0.8	55.3%	52.9%
	Std Dev	3.1	2.2	39.0%	42.1%
Phase matched	Bias	-0.6	-0.4	63.4%	61.6%
	Std Dev	1.7	1.5	58.3%	58.4%
Phase matched single layer	Bias	-0.05	0.2	77.4%	73.3%
	Std Dev	1.3	1.1	77.3%	73.7%

Conclusions from CALIPSO Comparisons

- ACHA NDE NOAA-20 performs well comparing to CALIPSO
- ACHA NDE NOAA-20 performs similarly to CLAVR-x
- ACHA NDE performs equally well for the Arctic
- Due to a tighter L1RD requirement, the percentages that meet specs for cloud temperature is less as expected

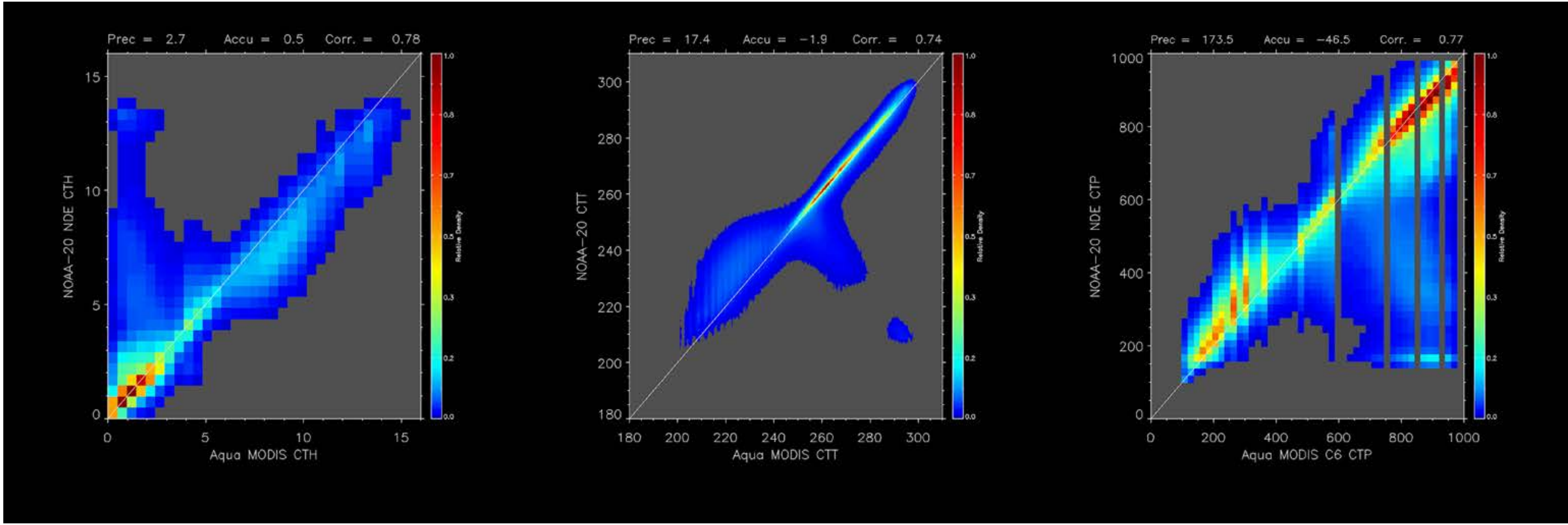
Comparison to AQUA/MODIS

Data and Methods

- 10 days of matchup files between NOAA-20 and Aqua MODIS from June, 2018 were used
- ACHA NDE NOAA-20 were compared to NASA MODIS
- ACHA values from all VIIRS footprints within a MODIS footprint were averaged to compare to MODIS

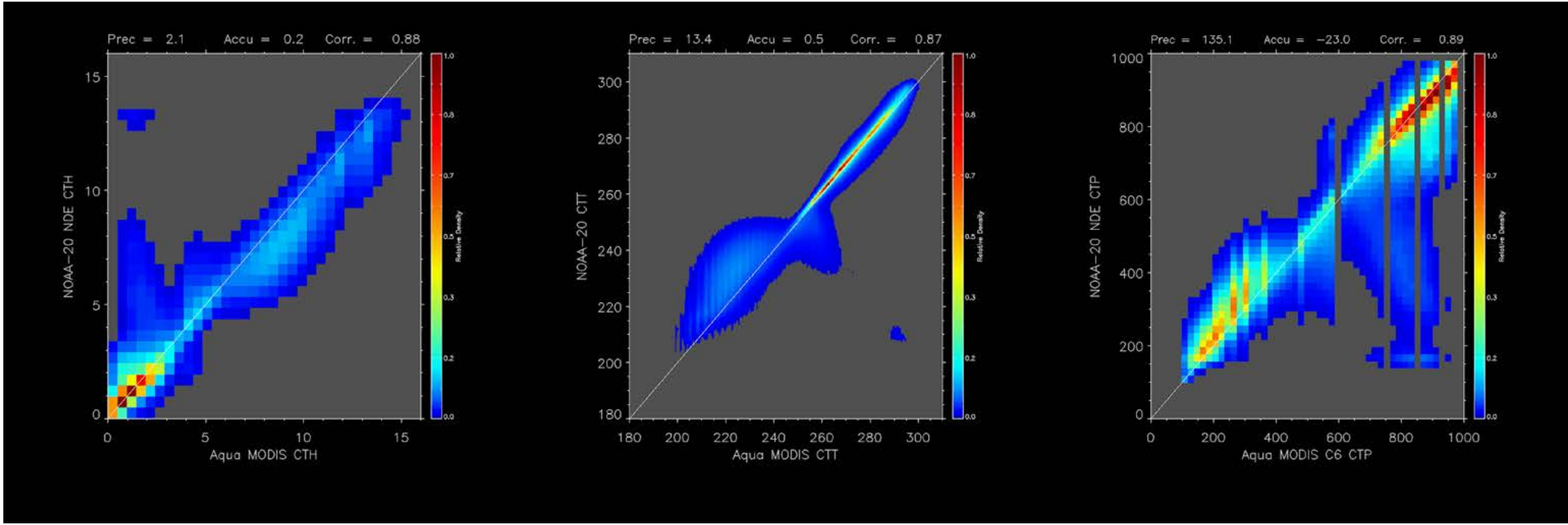
No filtering

CTH CTT CTP



Phase-matched

CTH CTT CTP



Evaluation Against NASA MODIS - No filtering

		Against MODIS C6	Against Caliop	Meet Specs - against MODIS	Meet Specs - against Caliop
CTH	Bias	0.5	-1.2	58.9%	55.3%
	Std Dev	2.7	3.1	54.7%	39.0%
CTT	Bias	-1.9	9.9	46.6%	35.2%
	Std Dev	17.4	21.3	37.6%	16.5%
CTP	Bias	-46.5	44.3	51.9%	57.2%
	Std Dev	173.5	169.3	35.7%	49.9%

Statics against Caliop are included for comparison purpose

Evaluation Against NASA MODIS - Phase matched

		Against MODIS C6	Against Caliop	Meet Specs - against MODIS	Meet Specs - against Caliop
CTH	Bias	0.2	-0.6	63.3%	63.4%
	Std Dev	2.1	1.7	62.4%	58.3%
CTT	Bias	0.57	5.5	50.0%	40.7%
	Std Dev	13.5	11.5	50.6%	24.0%
CTP	Bias	-24.8	14.5	56.7%	65.5%
	Std Dev	132.9	92.5	50.2%	65.%

Statics against Caliop are included for comparison purpose

Conclusions from MODIS Comparisons

- ACHA NDE NOAA-20 performs well comparing to NASA MODIS
- The specs shows ACHA NDE compares better with NASA MODIS than with CALIPSO/CALIOP. This is due to the reason that both ACHA and NASA MODIS are IR based retrievals.

Investigation of Issues

- NDE has unrealistic values for cloud height and pressure, but not for cloud temperature
- This is due to bad NWP files and has been fixed in ACHA
- The issue will be fixed in the DAP delivery to NDE in August 2018

Beta Maturity Conclusions

- There are minor issues with the NDE ECM v1r2 on NOAA-20.
- Based on analysis of offline runs of the SAPF, we feel most of these issues stem from NDE and **not** the ACHA or SAPF, and can be fixed.
- The ACHA run in CLAVR-x and in SAPF (run locally) appears not to suffer from these issues.
- **The Cloud Team recommends Beta Maturity at this time.**

Pathway to Provisional

- We expect to apply the same activities to be conducted for Provisional Maturity:
  - We are gathering an archive of golden days where we save SDRs and EDRs spread from May 2018 to August 2018. This collection is underway.
  - Intercomparisons with CALIPSO, NASA MODIS and S-NPP.
  - We will focus on specific scenarios, for example, the differences seen in descending mode, to improve ACHA N20 performances.
  - Attempt to bring in Polar Winds results.

Risks for Provisional

Currently outstanding issues, unless fixed by handover, may prevent declaration of Provisional Maturity:

- **NDE processing issues (Moderate)**
  - Missing granules in NDE processing
    - Currently being addressed in June 2018 DAP delivery. Expected operations in late 2018

Future Plans of ACHA

- We will work with Phase team and explore methods that allow ACHA to try a different phase value when ACHA retrievals fail.

- We will continue to expand the ACHA multi-layer capability but VIIRS provides limited spectral information for this.

- If successful, our JPSS PG RR project should develop a capability to leverage off NUCAPS to improve the VIIRS height performance.