NOAA-20 VIIRS Enterprise Cloud Base Height (CBH)
Validated Maturity Review

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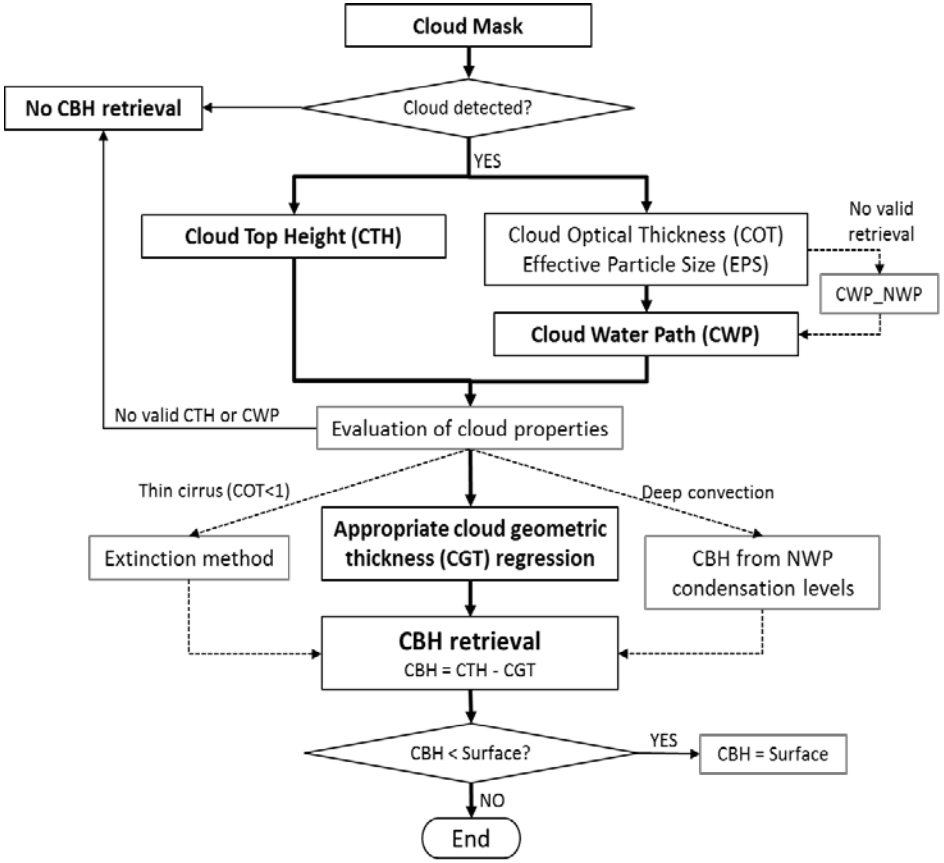
Product Overview - Enterprise Cloud Base Height



- Estimate the base height of the uppermost cloud layer, based upon statistical relationships trained by cloud geometric thickness (CGT), cloud top height (CTH), and cloud water path (CWP) observations from A-Train satellites
- **Require CTH and CWP as main input, CBH = CTH – CGT**
- Additional handling for thin cirrus (extinction method) and deep convection (supplementary NWP data)

- Errors in upstream retrievals of Cloud Mask, CTH and CWP directly impact the accuracy of CBH retrieval
- **Optimal for single layer clouds**, and may not be 'ceiling' for multi-layered cloudy scenes, comprising uncertainties of the upstream retrievals.
  - User Quick guide: http://rammb.cira.colostate.edu/training/visit/quick_guides/QuickGuide_JPSS_VIIRS_CBH.pdf

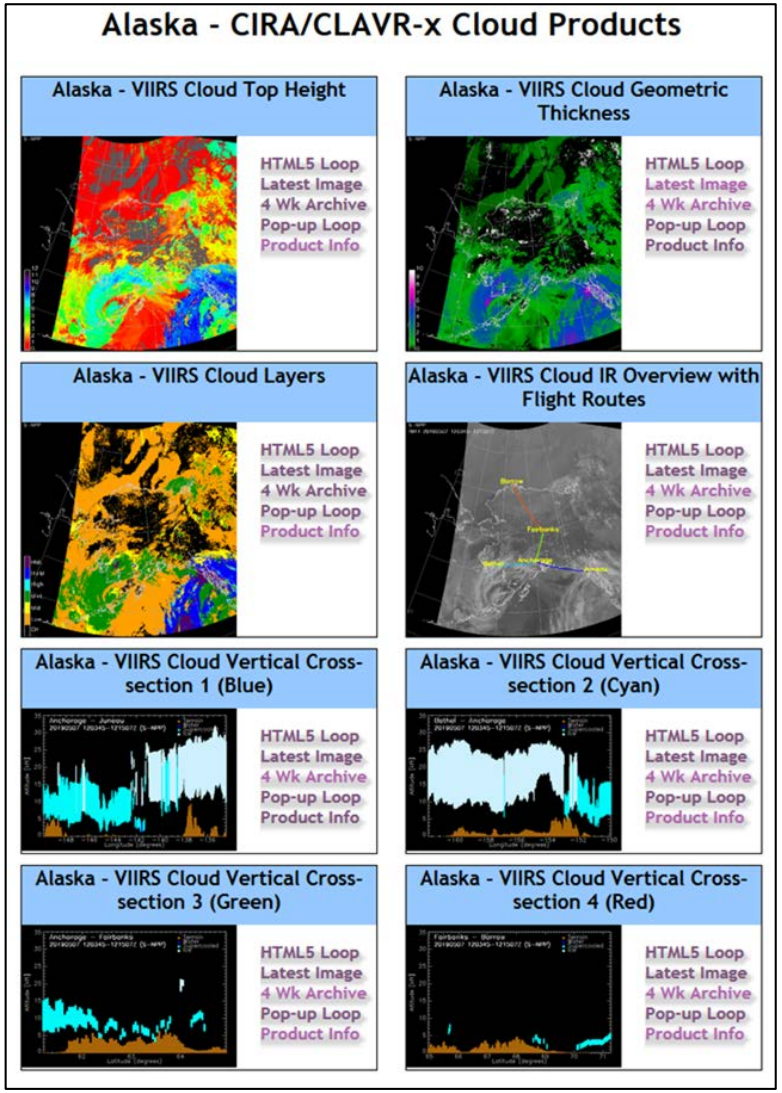
Product Requirements and Processing Algorithms

- **Requirements Cloud Base Height**
  - JERD-2476 The algorithm shall produce a cloud base height product that has a measurement precision of
    - **2.0 km for COT >=1 and 3.0 km for COT < 1**
  - JERD-2477 The algorithm shall produce a cloud base height product that has a measurement accuracy of
    - **2.0 km for COT >=1 and 3.0 km for COT < 1**

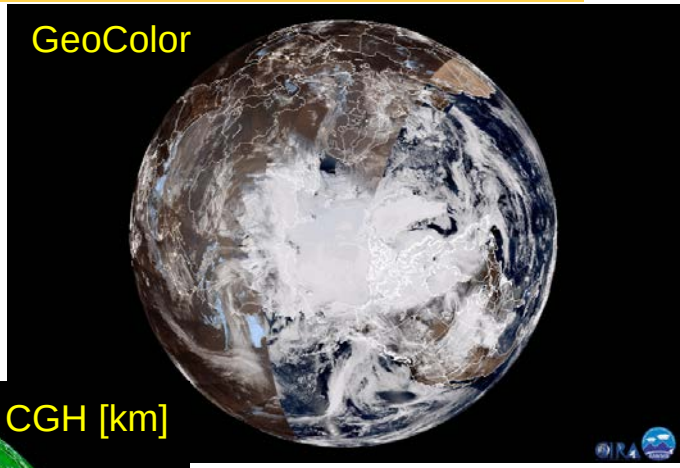
- Operational for NOAA-20 VIIRS as well as S-NPP VIIRS
  - Completed maturity reviews: *Beta* in July 2018, *Provisional* in Oct 2018
- **Currently being processed within SAPF at NDE: Operational Code base v2r0** (February 2018 Science code delivery)
- The CBH information is made available to improve the Cloud Cover and Layers product (*not in the current DAP*)

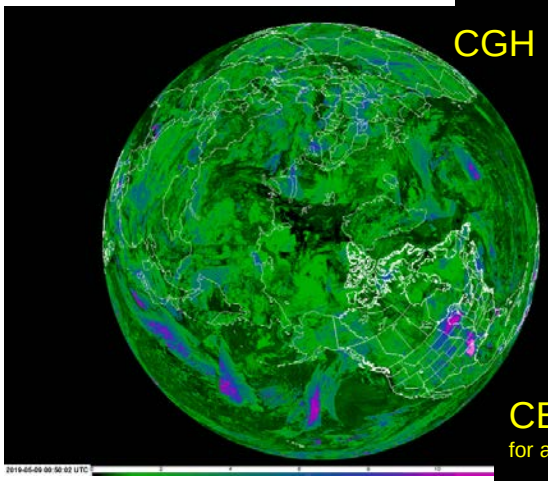
Monitoring VIIRS CBH/CGT products at CIRA

VIIRS imagery and cloud products over Alaska ↓
http://rammb.cira.colostate.edu/ramsdis/online/npp_viirs_arctic.asp

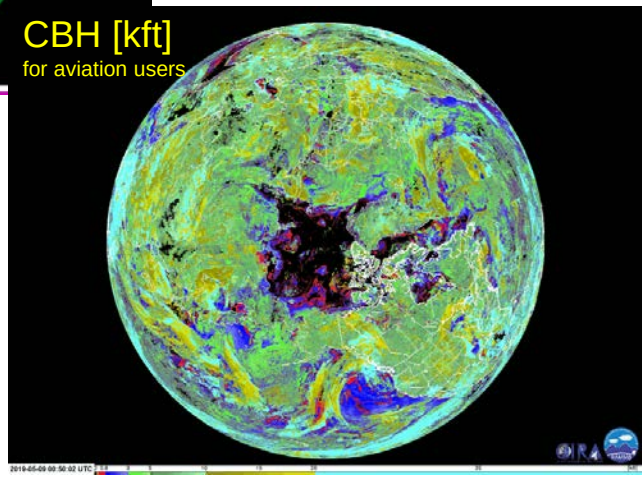


Polar SLIDER for global VIIRS imagery and cloud products →



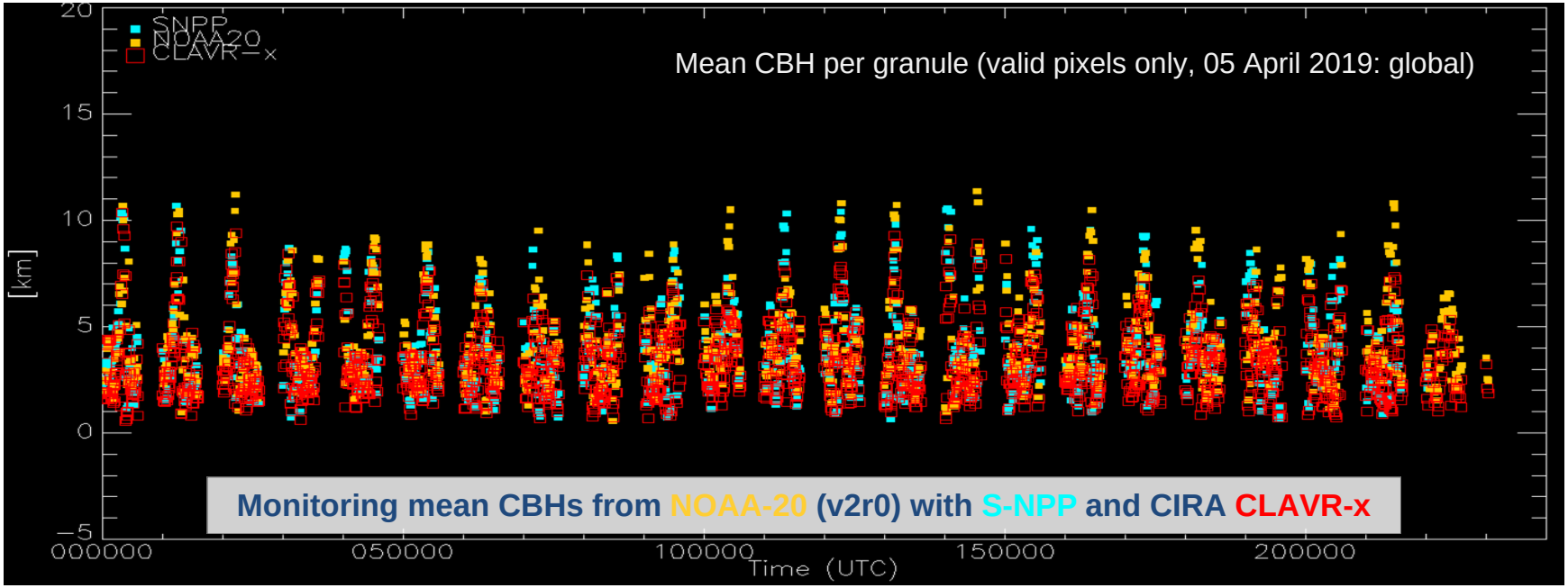


http://rammb-slider.cira.colostate.edu/?sat=jpss



Algorithm Performance Evaluation

- Monitoring time series to check consistency between S-NPP and NOAA-20 (both v2r0) algorithm operations
- Examine CBH and CGT (cloud geometric thickness=CTH-CBH), compared with CIRA's CLAVR-x output
- Case studies to identify issues for the individual granules
- Compare with ARM (U.S. DOE Atmospheric Radiation Measurement) site measurements (ceilometer and lidar) for selected periods



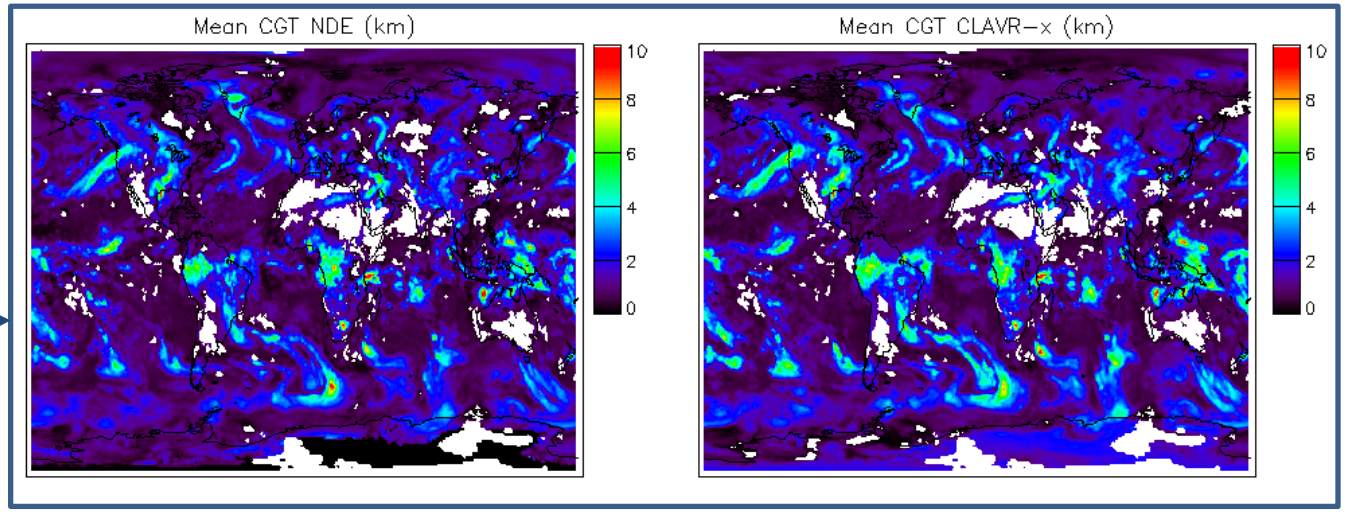
Enterprise CBH v2r0 Integration Results

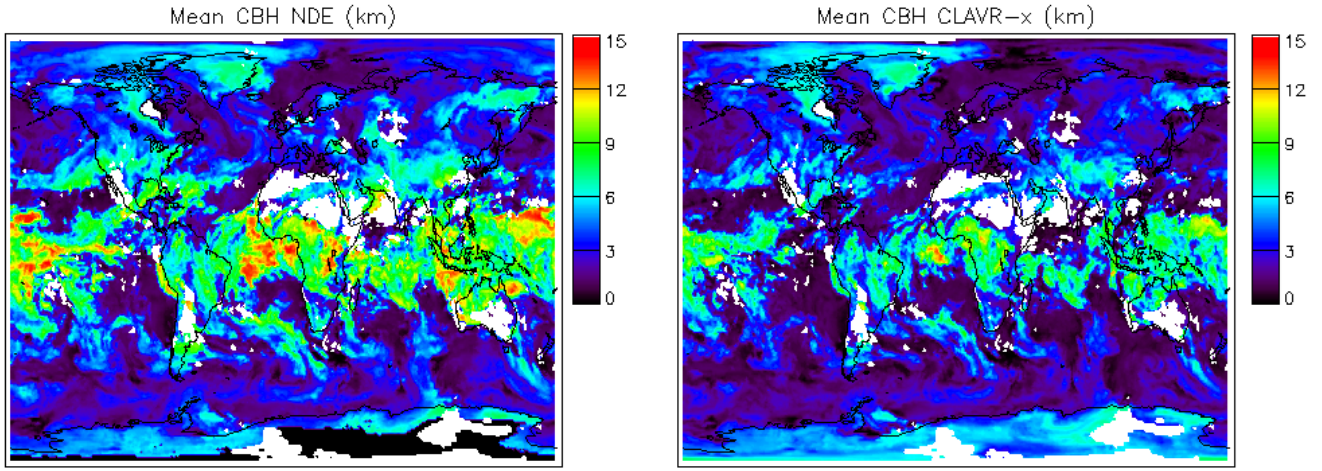
Compare global CGT and CBH (1ºx1º) from NOAA-20 and CIRA's CLAVR-x

CBH = CTH – CGT

- **The main part of the current CBH algorithm (obtaining CGT) works normally**
- CBH is highly dependent on CTH (slight CTH changes directly impact on CBH)
- CBH differences primarily from cloud top computed by different cloud phase versions between NDE and CIRA's CLAVR-x, and nighttime CWP input (different GFS versions)

934 NOAA-20 VIIRS granules (07 April 2019)





Enterprise v2r0 Integration Results

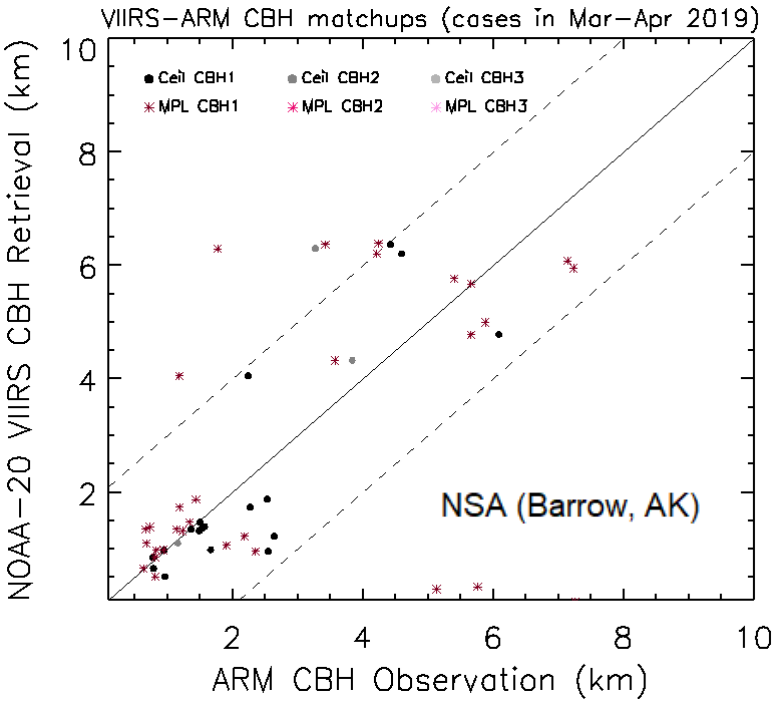
Compare global CBHs from NOAA-20 with CIRA's CLAVR-x output

Case	No. of granules examined (global)	Valid CTH but Invalid CBH (%)	Out of spec (%) compared with CLAVR-x (within 200-m CTH accuracy range)
Selected cases Mar – Apr 2019	3,620	2.93	0.87

- The CBH algorithm with NOAA-20 VIIRS (v2r0) is working normally as long as the upstream cloud retrievals and supplementary data are valid (CTH, CWP from DCOMP in daytime, NWP at night)
- "Invalid CBH" pixels with valid CTH values: primarily due to no CWP input
- "Out of spec" pixels are primarily caused by CWP input discrepancies between v2r0 and CIRA's CLAVR-x (by examining individual granules)
- Further improvement is ongoing for nighttime (DNB NLCOMP+NWP+ATMS) and multi-layer clouds (leveraging CIRA's GOES-R PGRR research using ABI+CloudSat+NWP with a machine learning approach)

CBH performance against ground measurements

- Ongoing evaluation efforts using ceilometer and lidar data from ARM sites (NSA in AK and SGP in OK)
  - VIIRS CBHs (NOAA-20 v2r0) for matchup cases in Mar-Apr 2019 (NSA) and Mar 2019 (SGP) upon data availability from each ARM site
  - Black/gray circles: ceilometer & Brown/red asterisks: lidar (MPL)
  - Despite lack of samples & limitations of surface obs, still **meet the L1RD spec**
  - Will continue more case studies and assessment for multi-layers (using CALIPSO)



VIIRS-ARM matchup cases *within 2-km CTH error range* (between VIIRS and ARM lidar) and no surface precip

- Examine v**alid CBHs within 2-km CBH spec** against surface lidar & ceilometer
- Slightly improved compared with v1r2 (Jun-Sep 2018 cases)

ARM site (cases)	Valid against Lidar	Valid against Ceilo
NSA (33)	79 %	96 %
SGP (14)	100 %	89 %

Errors [km]	MAE	RMSE	Std of error
Lidar	1.13	1.90	1.54
Ceilometer	0.89	1.43	1.14

CBH performance against CALIPSO

- Evaluation of CBH compared to CALIPSO (Target: optically thin clouds COT < 1)

Attribute Analyzed	L1RD Threshold	On-orbit Performance from CALIOP		Meet Requirement?
CBH	3.0 km when τ (COT) < 1	MAE within 2-km CTH accuracy range	0.4 km	Yes

- Since CTH errors directly impact on CBH, examine cloudy pixels with CTH within 2-km accuracy range compared to CALIPSO cloud top

Errors [km]	MAE	RMSE	Std of error
CALIPSO 162 granules VIIRS 4977 granules (Mar 2019) 864,494 matchup points "within CTH spec" (Thin with COT < 1: 24 %)	All clouds: 0.5 Thin only: 0.4	All clouds: 1.7 Thin only: 1.5	All clouds: 1.6 Thin only: 1.5

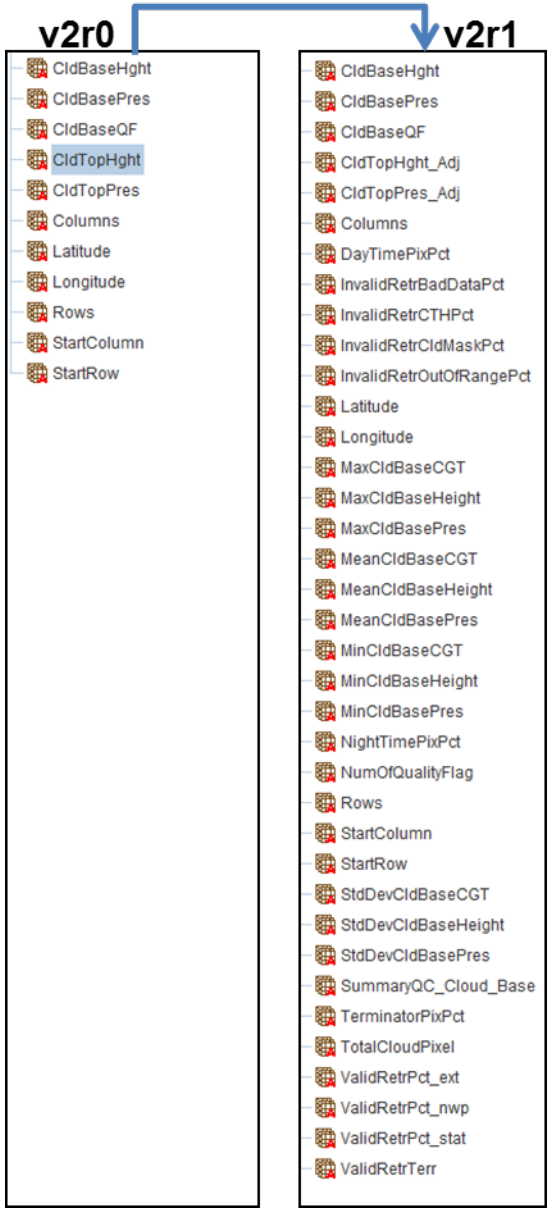
- Meet the spec for all clouds as well, but CloudSat data will be added for a more robust evaluation on thicker clouds including deep convection, which data processing recently started again after a long maneuver period to transition the orbit last year (no data coverage for v2r0 yet)

Quality Flags and Metadata Update

- Current variable name: CldBaseQF

Flag Value	Description
0	Valid retrieval from the statistical method
1	Invalid due to the upstream input being invalid or clear
2	CBH = Terrain due to CBH lower than Terrain
3	Out of range due to CBH < minCbh (0 km) or CBH > maxCbh (20 km)
4	Invalid due to CBH >= CTH
5	Valid retrieval from the extinction method
6	Valid retrieval from NWP for deep convection

- Diagnostic metadata output will be updated in v2r1 ⟶ (more effective long-term monitoring)



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 (Check List, 1 slide)

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)	Yes
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes for S-NPP No for NOAA-20
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	Yes

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 and Path Forward

- The NDE Enterprise **CBH** algorithm (**ACBA**) with NOAA-20 VIIRS (v2r0) is working nominally without serious issues (valid day/night operations) as long as the upstream cloud retrievals and supplementary data are valid (Cloud Mask, CTH, CWP from DCOMP in daytime, NWP at night)
- ACBA is highly dependent on ACHA performance. Will continue ACBA monitoring along with ACHA updates in next DAPs in collaboration with the CIMSS team
- **ACBA meets the spec** well when cloud top is in an accurate range through this evaluation using CLAVR-x, ARM measurements and CALIPSO
- CloudSat data will be added again for long-term validation as data processing recently restarted after a maneuver period to transition its orbit last year
- Will continue to support the STAR ASSISTT for its optimal operation and long-term monitoring within the operational frame (diagnostic metadata update in v2r1)
- Will support validation and monitoring for CCL products when the cloud base component is made available for the CCL algorithm
- Continue to improve training and display tools for users with information clearly stating limitations and applications (supporting JPSS Aviation Initiative)
- **Recommend ‘Validate Maturity’**