L2 retrieval product intercomparisons

EarthCARE L2 science
APRIL/CLARA/DORSY final presentations

Shannon Mason (shannon.mason@ecmwf.int)

with thanks to Dave for tireless support on the synthetic EarthCARE scenes, and all L2 algorithm developers

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Outline

- Evaluation & intercomparison of EarthCARE L2 retrieval products for 3 simulated EarthCARE scenes
  - Opportunity to explore limitations (& set expectations) of EarthCARE retrievals based on instrument simulators: e.g. what fraction of cloud is “recoverable” by ATLID vs CPR, and by their synergy?
  - Improved understanding of the full suite of EarthCARE processors & interactions across teams
  - Drives progress toward standardized/automated evaluation and intercomparison tools (e.g. quicklooks & evaluation metrics):
    - mproved homogeneity of data products (e.g. variable names, retrieved quantities, uncertainties, etc.)
    - Rapid discovery of bugs & understanding of reasons for expected differences
- Challenges:
  - Comparison across different retrieval geometries (passive across-swath; layer-wise or profiling at nadir; 3D scene reconstructions)
  - Systematic evaluation of all quantities (extinction, effective radius, mass content, lidar ratio, etc.) to help identify compensating biases

Ice cloud & snow
Passive: M-COP
Active: A-ICE & C-CLD
Composite: ACM-COM
Synergetic: ACM-CAP

Liquid cloud
Passive: M-COP
Active: C-CLD
Composite: ACM-COM
Synergetic: ACM-CAP

Rain
Active: C-CLD
Synergetic: ACM-CAP

Aerosols
Passive: M-AOT
Active: A-EBD, A-AER
Layer-wise: A-LAY, AM-ACD
Synergetic: ACM-CAP

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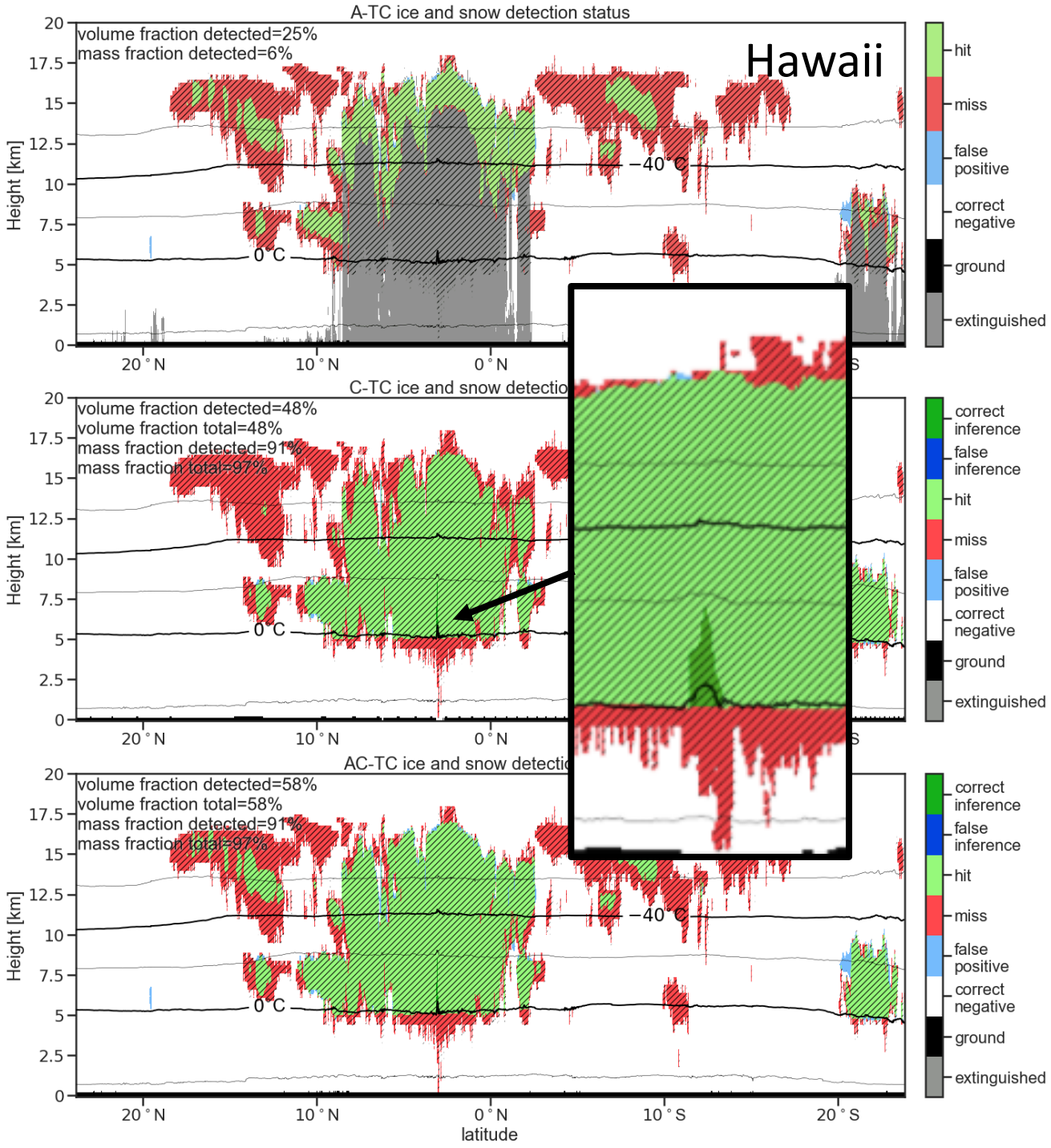
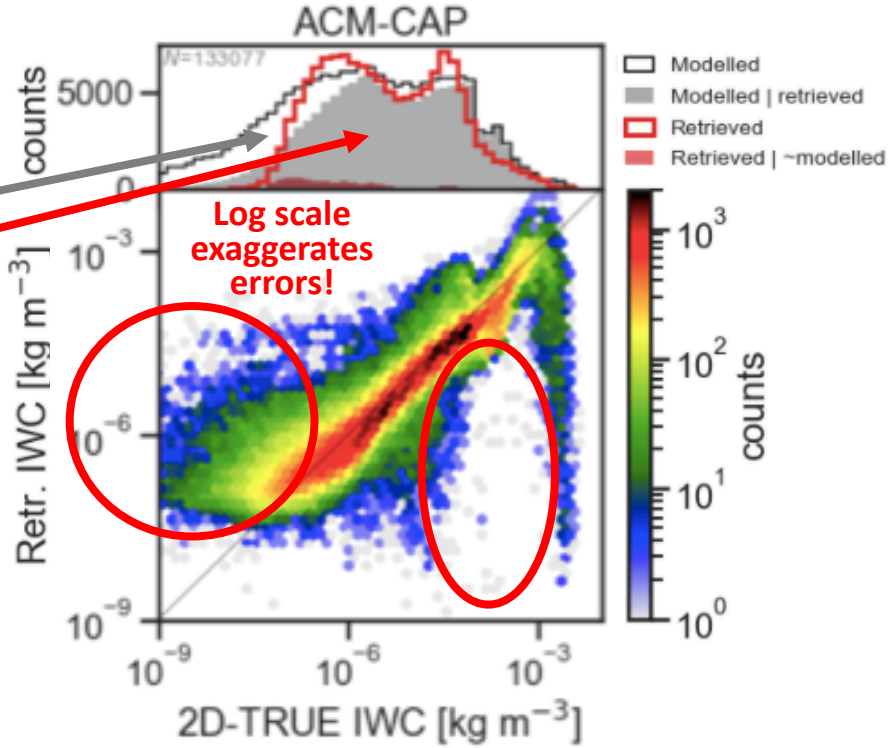
Ice clouds and snow: detection & classification

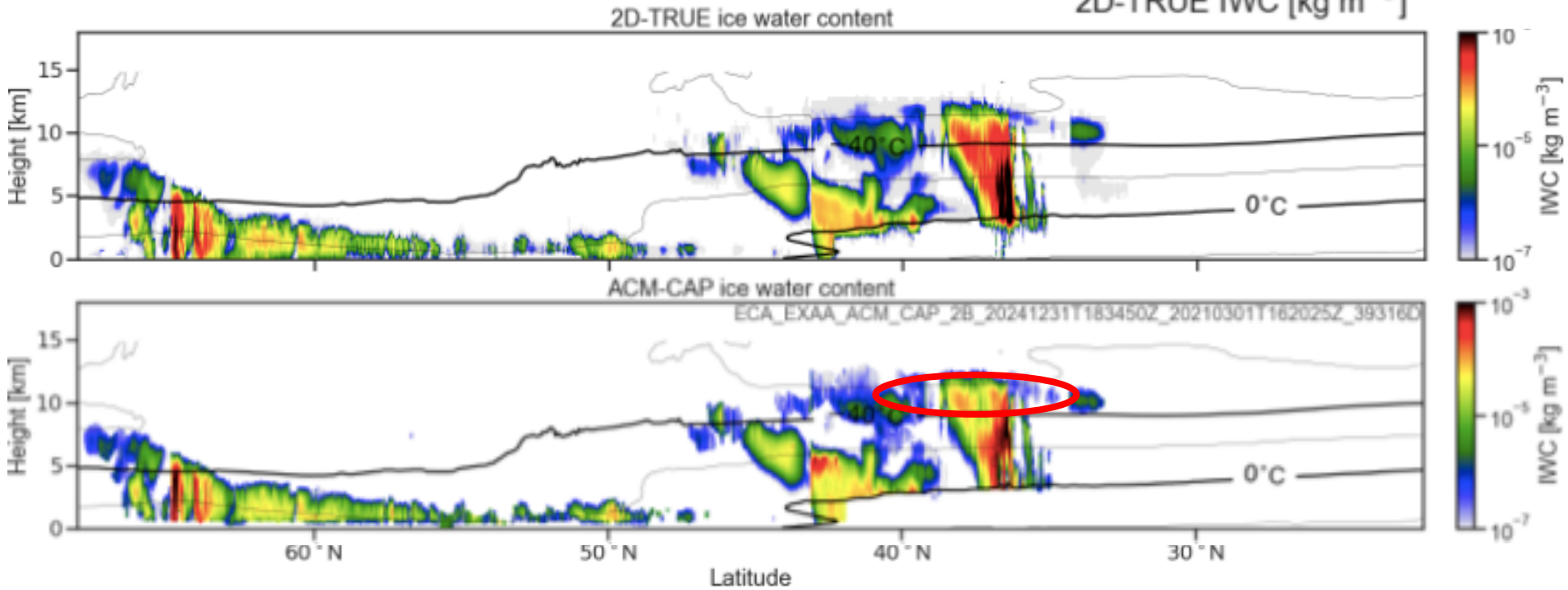
- ATLID (A-TC):
  - Detection of radiatively important cloud-tops and thin cirrus **(25% of ice clouds by volume)**
  - Quickly extinguished in optically thick ice clouds **(6% of ice and snow by mass)**
- CPR (C-TC)
  - Detects large ice & snow, but misses cirrus **(50% of ice clouds by volume; 91% of ice and snow by mass)**
  - 94-GHz radar extinguished in the convective core around 10 km wide **(represents 6% of total ice mass in this scene)**
- Synergy (AC-TC):
  - Resolves both cirrus and snow **(60% of ice by volume)**
  - **Lidar contributes very little to total mass of ice, but cloud-top location and microphysics are critical for radiation.**



Ice clouds and snow: retrievals

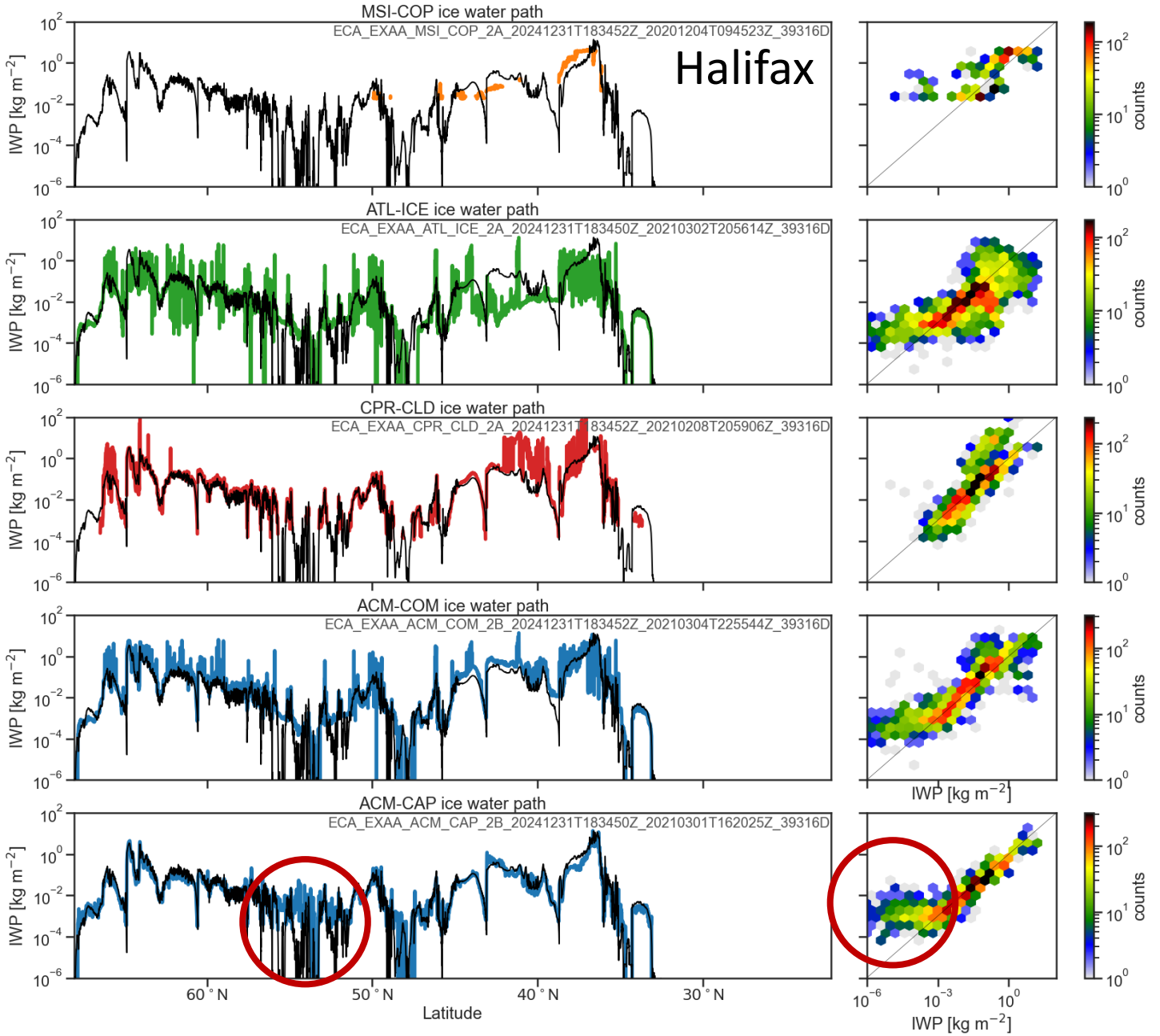
- ATLID (A-ICE): accurate retrieval of ice at cloud-top; good fit to low-to-moderate IWCs but misses high IWC
  - ***Grey shading vs black line:*** *what can be retrieved?*
  - ***Red line vs grey shading:*** *how is the retrieval biased?*
- CPR (C-CLD): high IWC retrieval is well-constrained; retrieval not attempted in convective core
- Composite (ACM-COM): benefits of both A-ICE and C-CLD, but some challenges in the "hand-over" regions
- Synergy (ACM-CAP): **smooth transition between ATLID- and CPR-dominated parts of the cloud; reduced random error in retrieval**





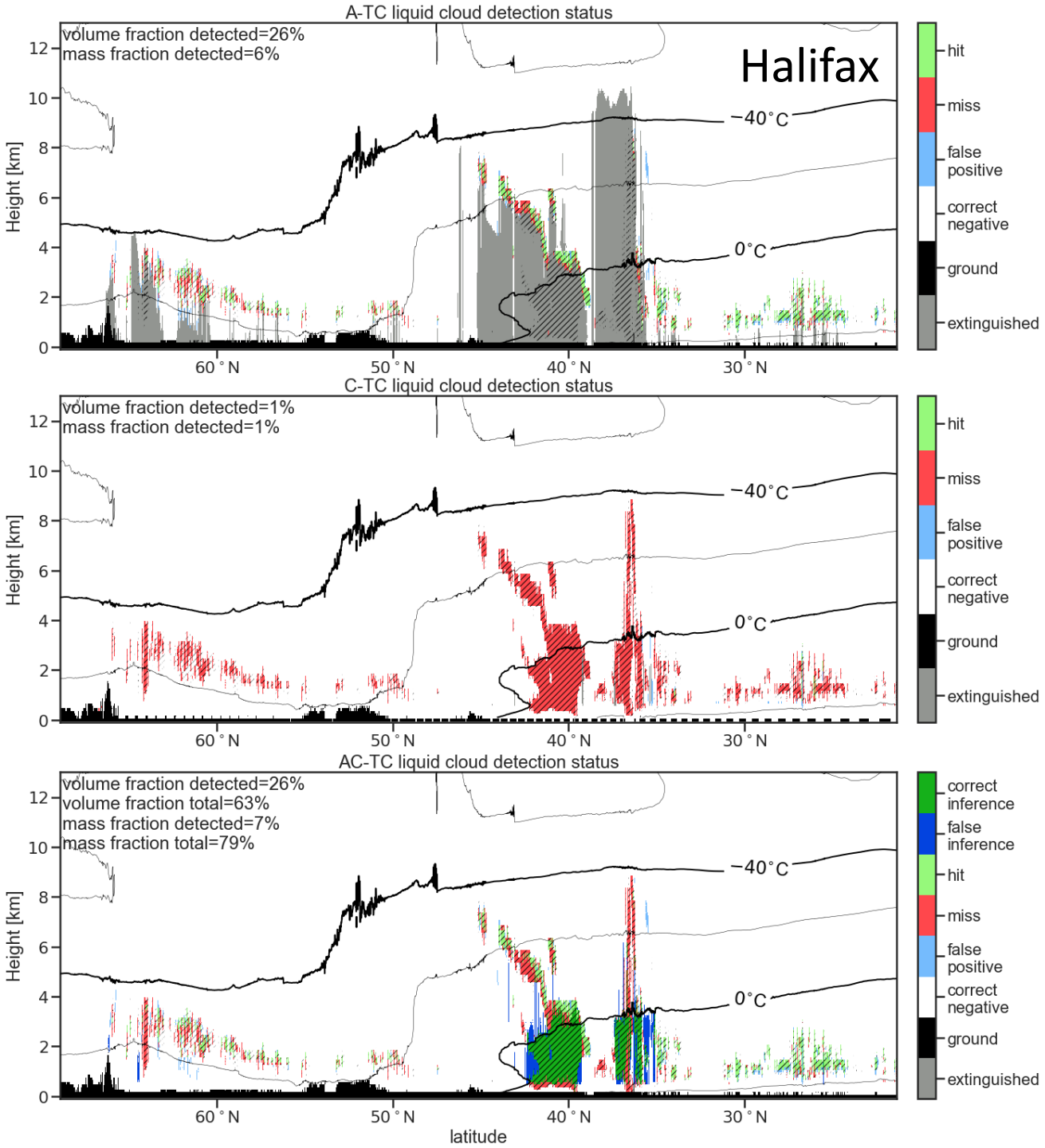
Ice clouds and snow: retrievals

- MSI (M-COP):
  - In daylit pixels @lower latitudes
  - Accurate in high-IWP pixels
- ATLID (A-ICE) & CPR (C-CLD):
  - noisy at high IWP
- Composite (ACM-COM):
  - Compositing between ATLID and CPR retrievals–accurate across medium and large IWPs (still some noise from ATLID)
- Synergy (ACM-CAP):
  - Smaller random error
  - Biased high at lowest IWPs (common to all ATLID ice retrievals)
    - Challenging shallow mixed-phase clouds: corresponding under-estimate of supercooled liquid



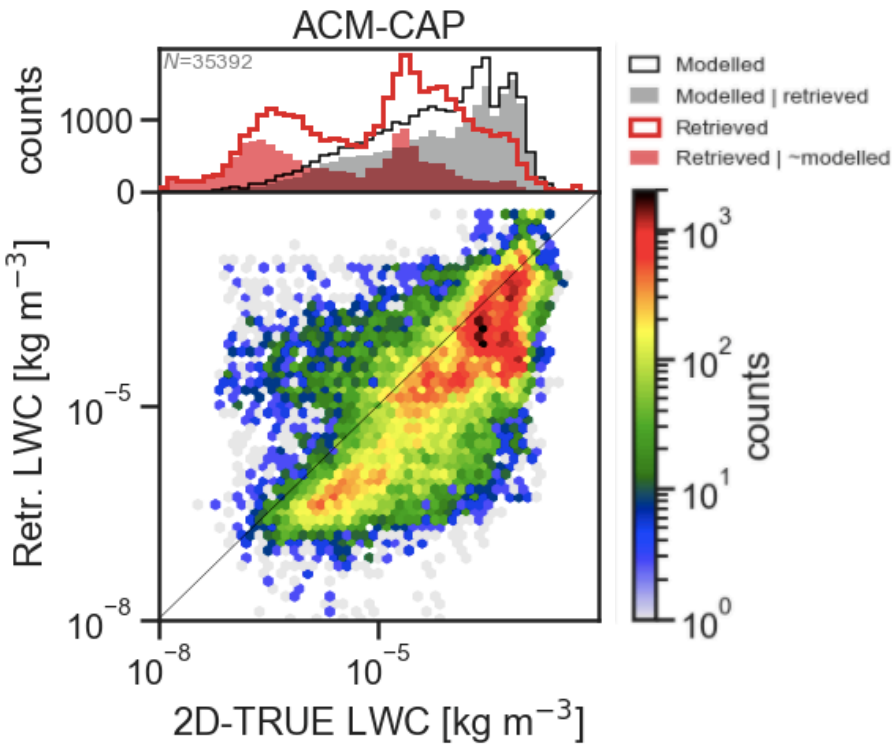
Liquid clouds: detection and classification

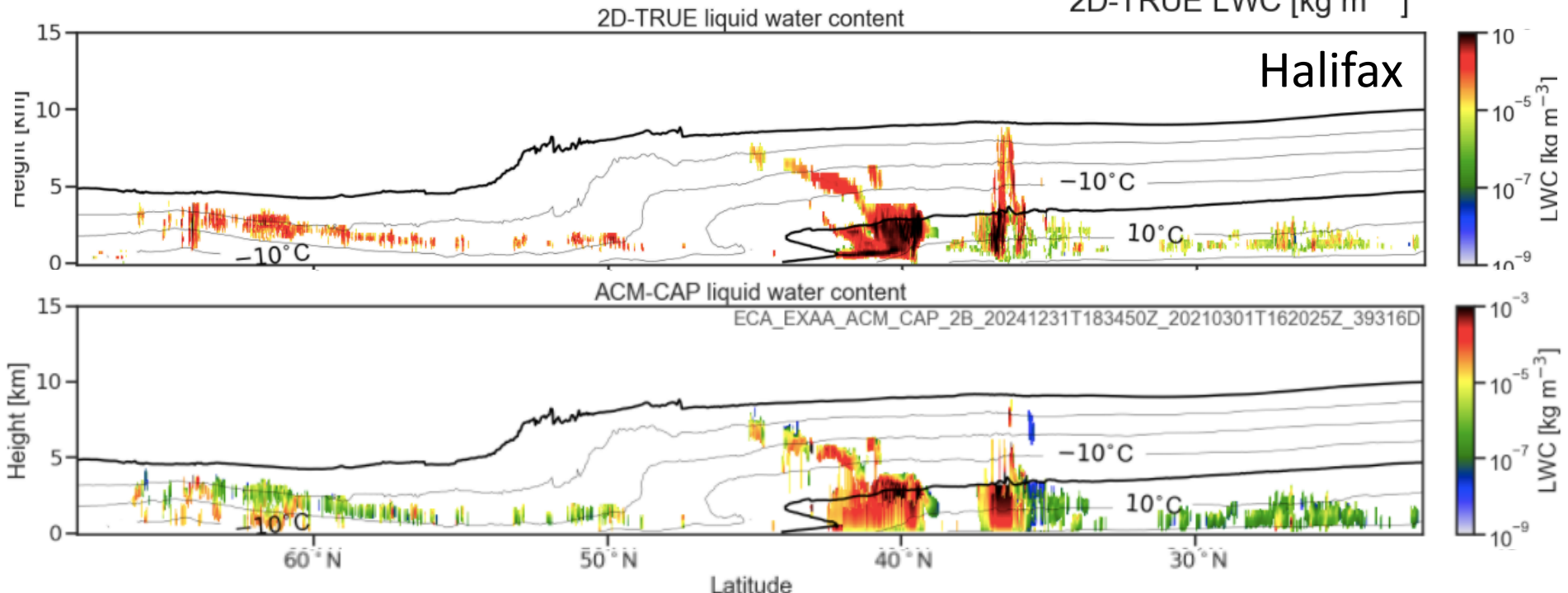
- ATLID (A-TC):
  - **Detects high-latitude mixed-phase and tropical boundary layer clouds**
  - **But quickly extinguished in optically thick clouds**:
    - identifies mid-level mixed-phase cloud layer
    - miss liquid in convective core and within stratiform rain
- CPR (C-TC):
  - Signal dominated by large ice and raindrops
  - **Liquid cloud identified very rarely (~1%)**
- Synergy (AC-TC):
  - In ACM-CAP, can we assume liquid cloud wherever CPR sees rain? **(63% by volume; 79% by mass)**
  - **Some false-positives, but improves rain & liquid retrievals, especially when constrained by solar radiances & radar PIA**



Liquid clouds: retrievals

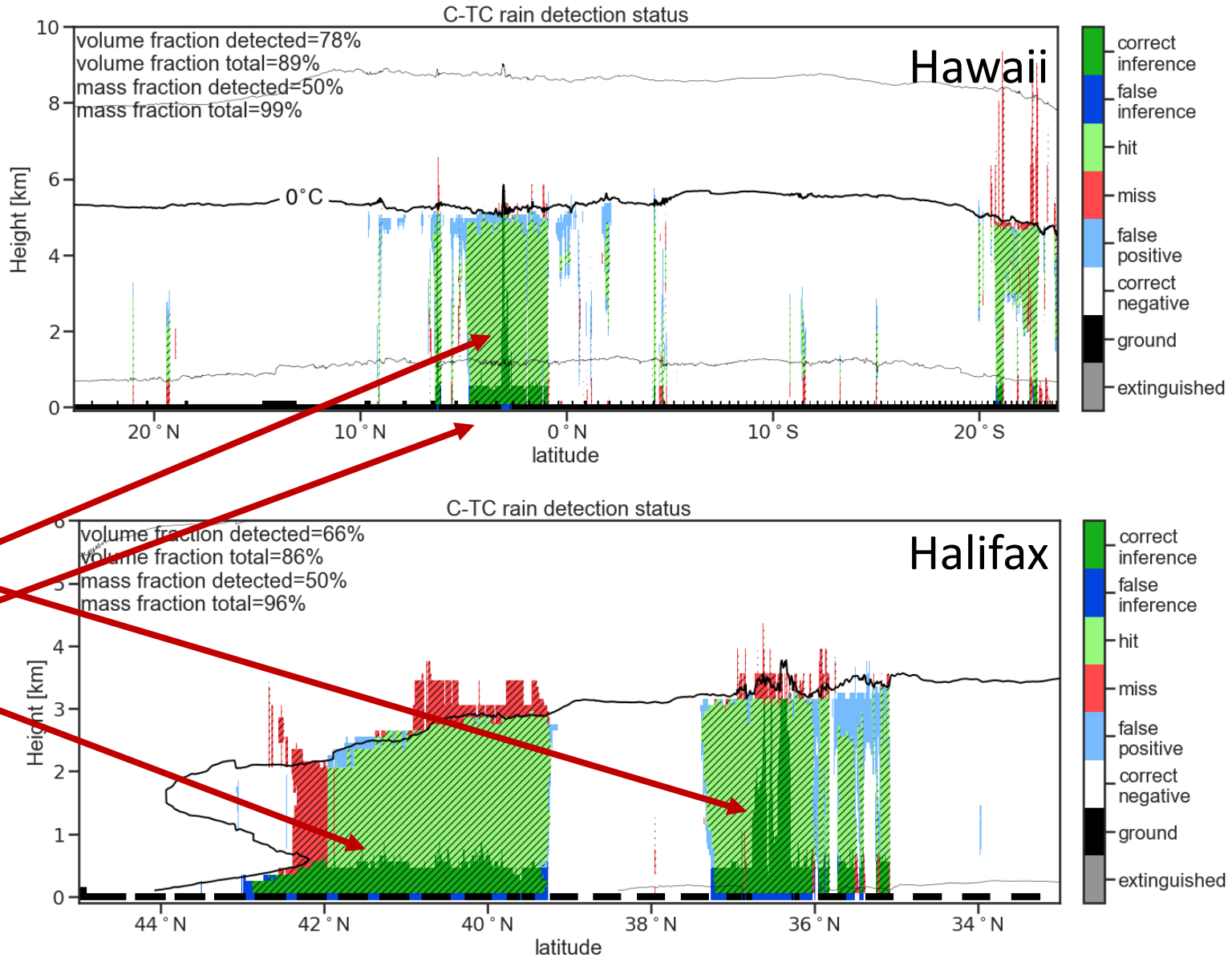
- CPR (C-CLD & ACM-COM):
  - **Very little liquid cloud to speak of; challenging for ACM-COM & radiative closure**
- Synergy (ACM-CAP):
  - Underestimates LWC in boundary layer clouds; in high-latitude mixed-phase clouds this could be a compensation between ice and liquid
  - **Retrieving liquid cloud in rain: improved, but still underestimated.**





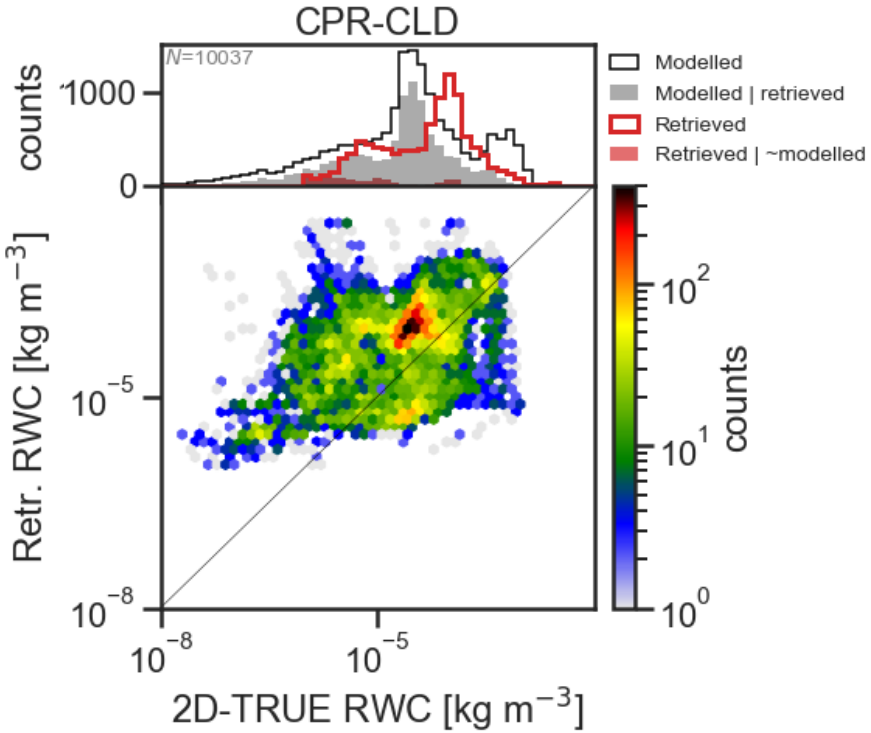
Rain: detection and classification

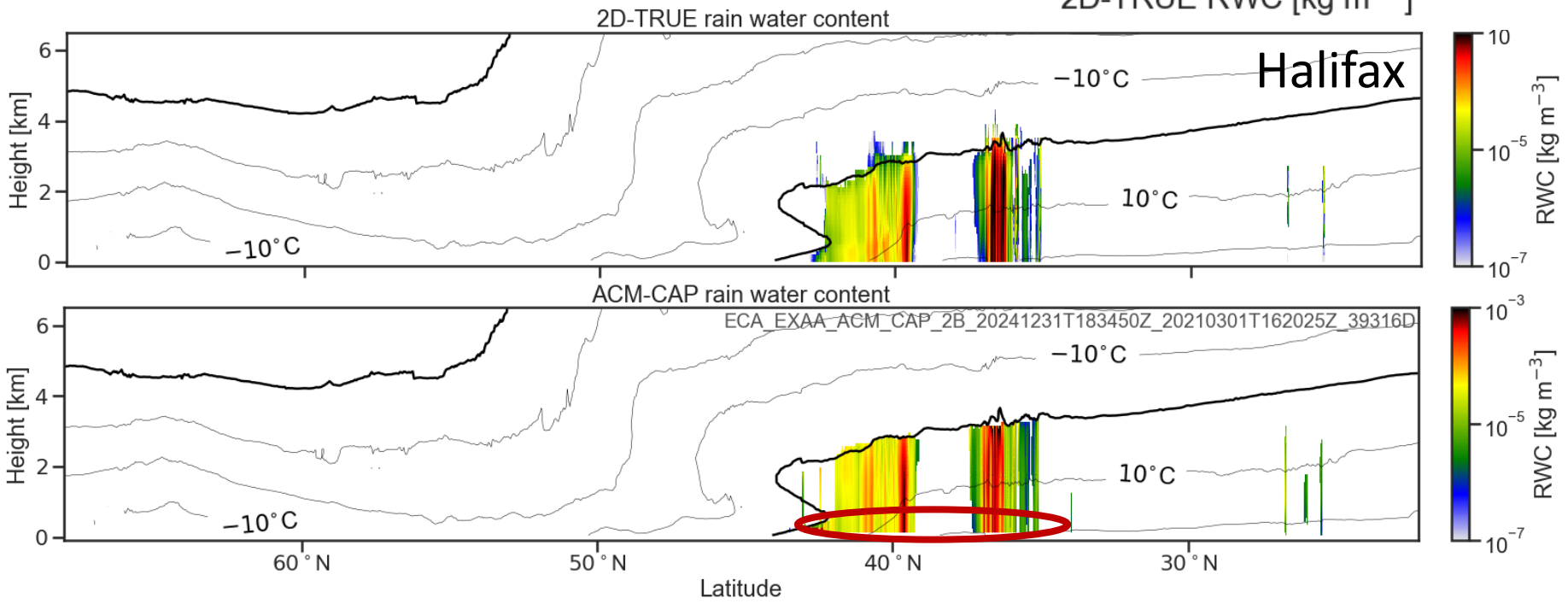
- CPR (C-TC & AC-TC):
  - Identifies 65—80% of rain by volume
    - Ambiguities around melting snow & supercooled rain
    - Surface clutter and radar extinction in heavy rain (R > 10 mm/h)
  - **Misses around 50% of rain by mass**
  - **…but can recover up to 99% of rain mass if we assume:**
    - Heavy rain after CPR extinguished
    - Rain continuous through the ground clutter



Rain: retrievals

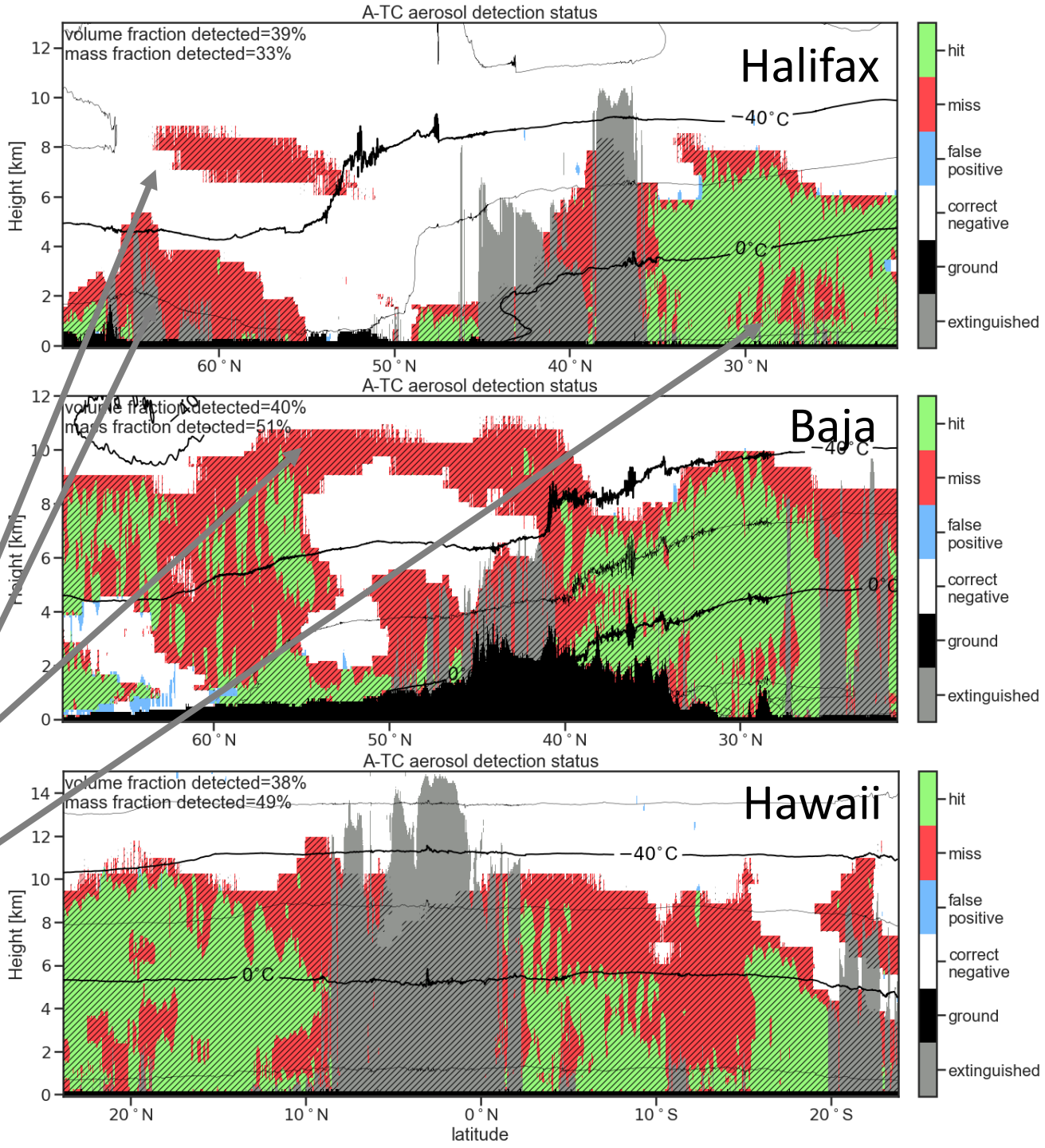
- C-CLD tends to over-estimate rain water content:
  - May be compensating for missing contributors to path-integrated attenuation from:
    - **Rain through the surface clutter region**
    - **Liquid cloud embedded in rain**
- ACM-CAP:
  - Doppler velocity used to retrieve rain drop size distribution
  - Radar path-integrated attenuation, a strong constraint on rain retrieval, also has a contribution from liquid cloud





Aerosols: detection and classification

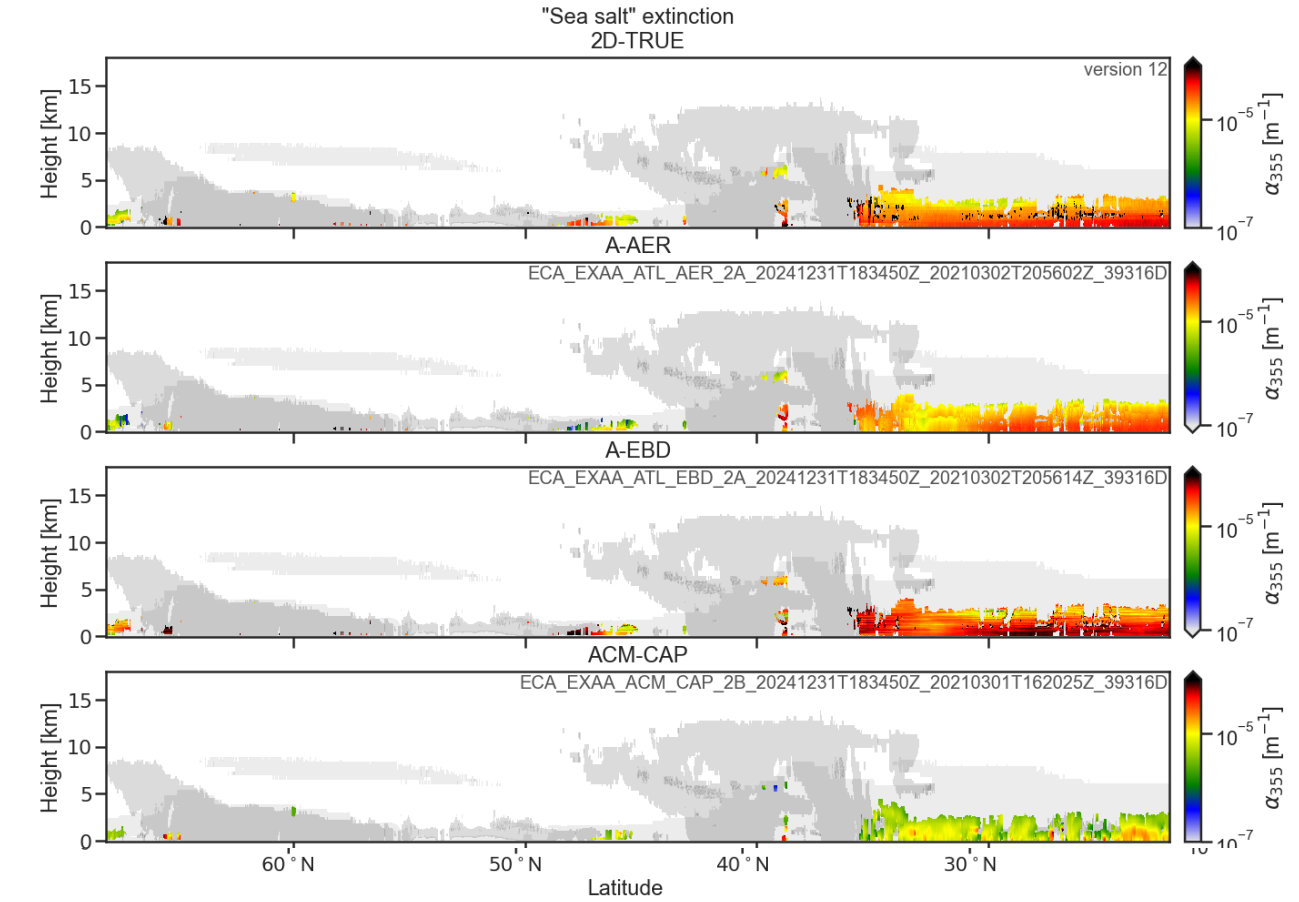
- HETEAC aerosol classification not evaluated here—just the presence of aerosols
- Using “low_resolution” A-TC product here: aerosol classification benefits from larger spatial scale than cloud & precipitation
- **Detecting 40% of aerosols by volume; 30 to 50% by mass:**
  - Some aerosol layers not detected above lidar noise
  - Lidar also frequently extinguished or obscured by cloud

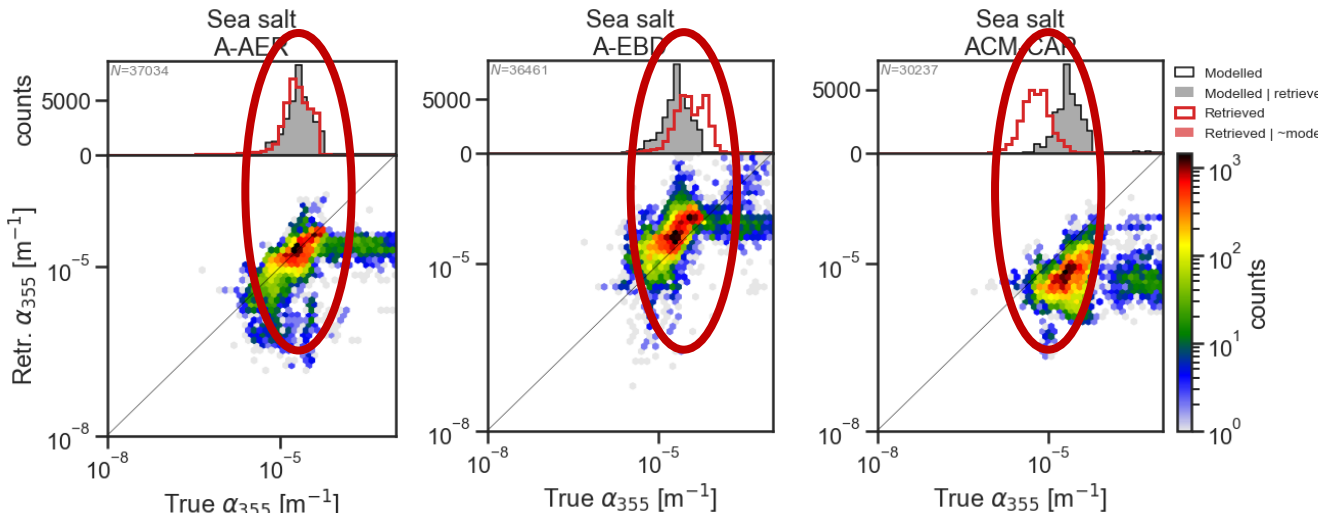


Aerosols: retrievals

Sea salt extinction (Halifax scene); a brief example—a lot of aerosol species & products to evaluate!

- A-AER: least biased aerosol extinction retrieval
- A-EBD: slightly over-estimates extinction, but better resolves vertical layers over large spatial scales
- ACM-CAP under-estimates sea salt extinction and doesn't resolve layered structure;
  - Overly-aggressive vertical smoothing?
  - Horizontal Kalman smoother is easily interrupted





Conclusions

- The simulated EarthCARE scenes provided a rare opportunity:
  - Access to a realistic “model truth” to quantify the performance and limitations of EarthCARE instruments, and formulate retrieval assumptions to compensate
  - Improved understanding of the full suite of EarthCARE retrieval products (and improved appreciation of their developers)
  - Cross-project intercomparison has led to identification of bugs and inconsistencies between processors, and in the test scenes
  - **Will serve us well going to CARDINAL activities…**
- Ongoing challenges:
  - Thorough and standardized evaluation for all products and all retrieved quantities
  - Expansion to include all passive and layerwise retrievals
  - Evaluating 3D scene construction against model truth