CATS Version 2 Aerosol Feature Detection and Applications for Data Assimilation

E. P. Nowottnick[1,2], J. E. Yorks[3], P. A. Selmer[4], S. P. Palm[4], D. L. Hlavka[4], R. M. Pauly[4], S. Ozog[5], M. J. McGill[3], and A. da Silva[6]

[1] NASA GSFC Code 614 [2] Universities Space Research Association [3] NASA GSFC Code 612 [4] Science Systems and Applications, Inc. [5] Earth System Science Interdisciplinary Center [6] NASA GSFC Code 610.1

1. Introduction

The Cloud – Aerosol Transport System (CATS) lidar has been operating onboard the International Space Station (ISS) since February 2015 and provides vertical observations of clouds and aerosols using total attenuated backscatter and depolarization measurements. From February – March 2015, CATS operated in Mode 1, providing backscatter and depolarization measurements at 532 and 1064 nm. CATS began operation in Mode 2 in March 2015, providing backscatter and depolarization measurements at 1064 nm and has continued to operate to the present in this mode. CATS level 2 products are derived from these measurements, including feature detection, cloud – aerosol discrimination, cloud and aerosol typing, and optical properties of cloud and aerosol layers. Here, we present changes to our level 2 algorithms, which were aimed at reducing several biases in our version 1 level 2 data products. These changes will be incorporated into our upcoming version 2 level 2 data release in summer 2017.

Additionally, owing to the near – real time (NRT) data downlinking capabilities of the ISS, CATS provides expedited NRT data products within 6 hours of observation time. This capability provides a unique opportunity for supporting field campaigns and for developing data assimilation techniques to improve simulated cloud and aerosol vertical distributions in models. We additionally present preliminary work toward assimilating CATS observations into the NASA Goddard Earth Observing System version 5 (GEOS-5) global atmospheric model and data assimilation system.

2. Modifications to Cloud – Aerosol Discrimination

Water clouds embedded in marine boundary layers proved challenging for the CATS version 1 cloud – aerosol discrimination algorithm. Owing to their high backscatter, this misclassification had significant implications for the aerosol optical thickness (AOT), as the lidar ratio for used aerosol layers if often greater than the lidar ratio used for water clouds. In the CATS version 2 cloud – aerosol discrimination algorithm, a horizontal persistence test has been implemented and modifications to algorithm thresholds have been made to reduce the misclassification of water clouds as aerosol.
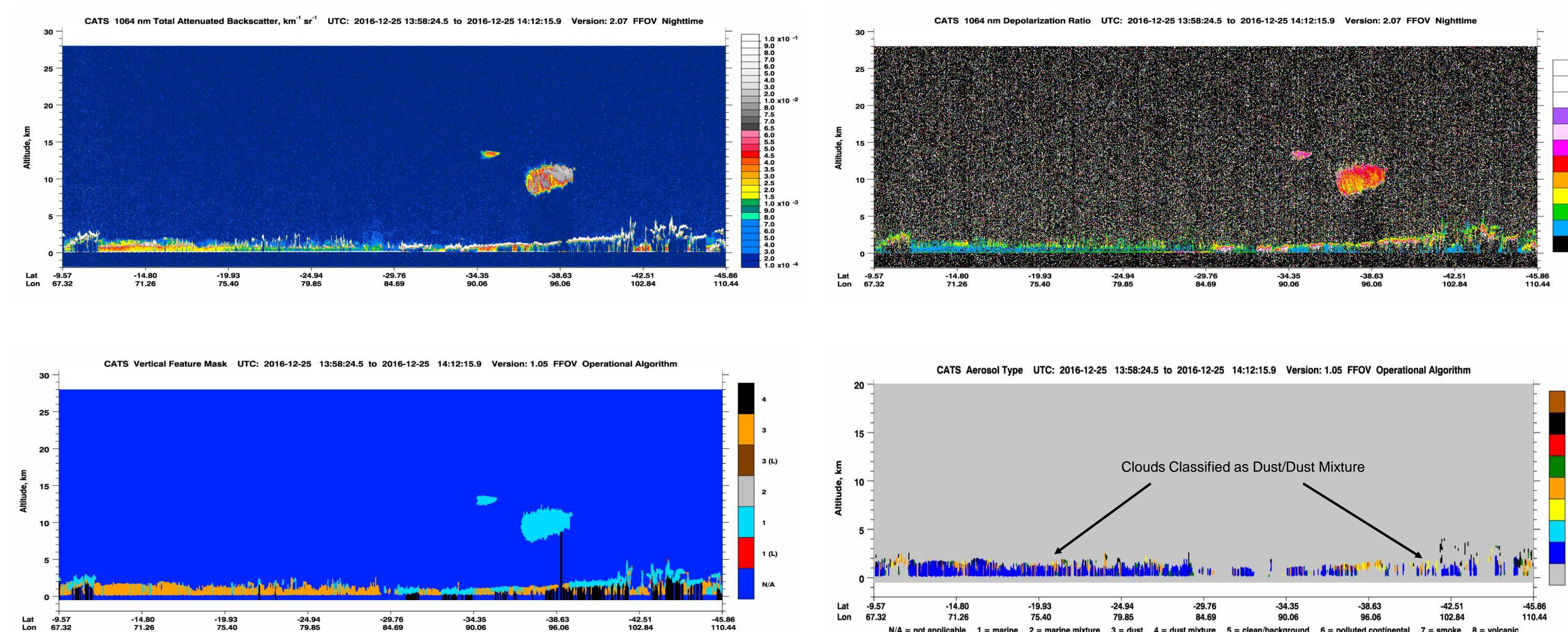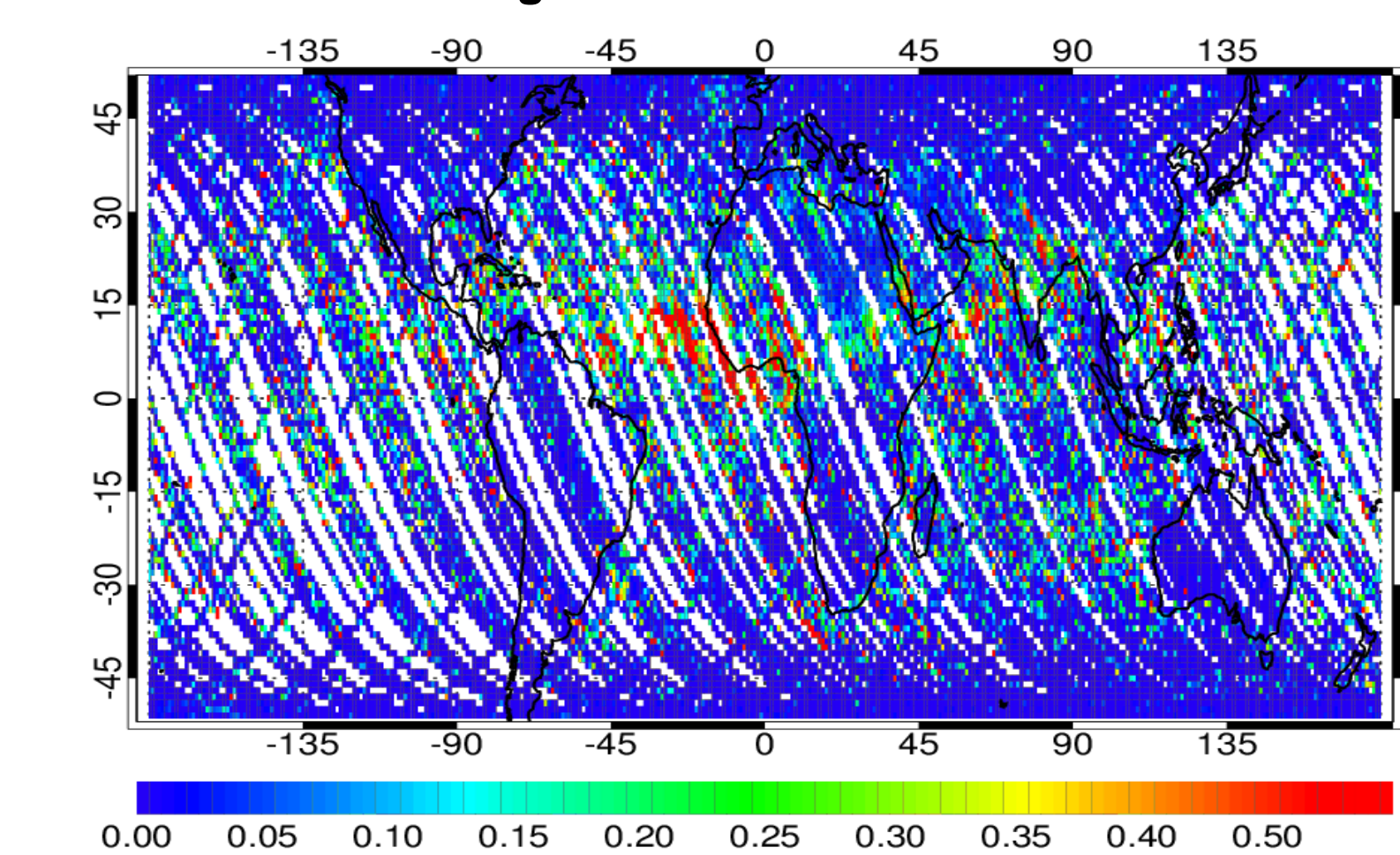

Figure 1. CATS 1064 nm Total Attenuated Backscatter (top left), depolarization ratio (top right), vertical feature mask (bottom left), and version 1 aerosol type (bottom right) for a marine boundary layer.

CATS Version 1 August 2015 Dust Mixture AOT

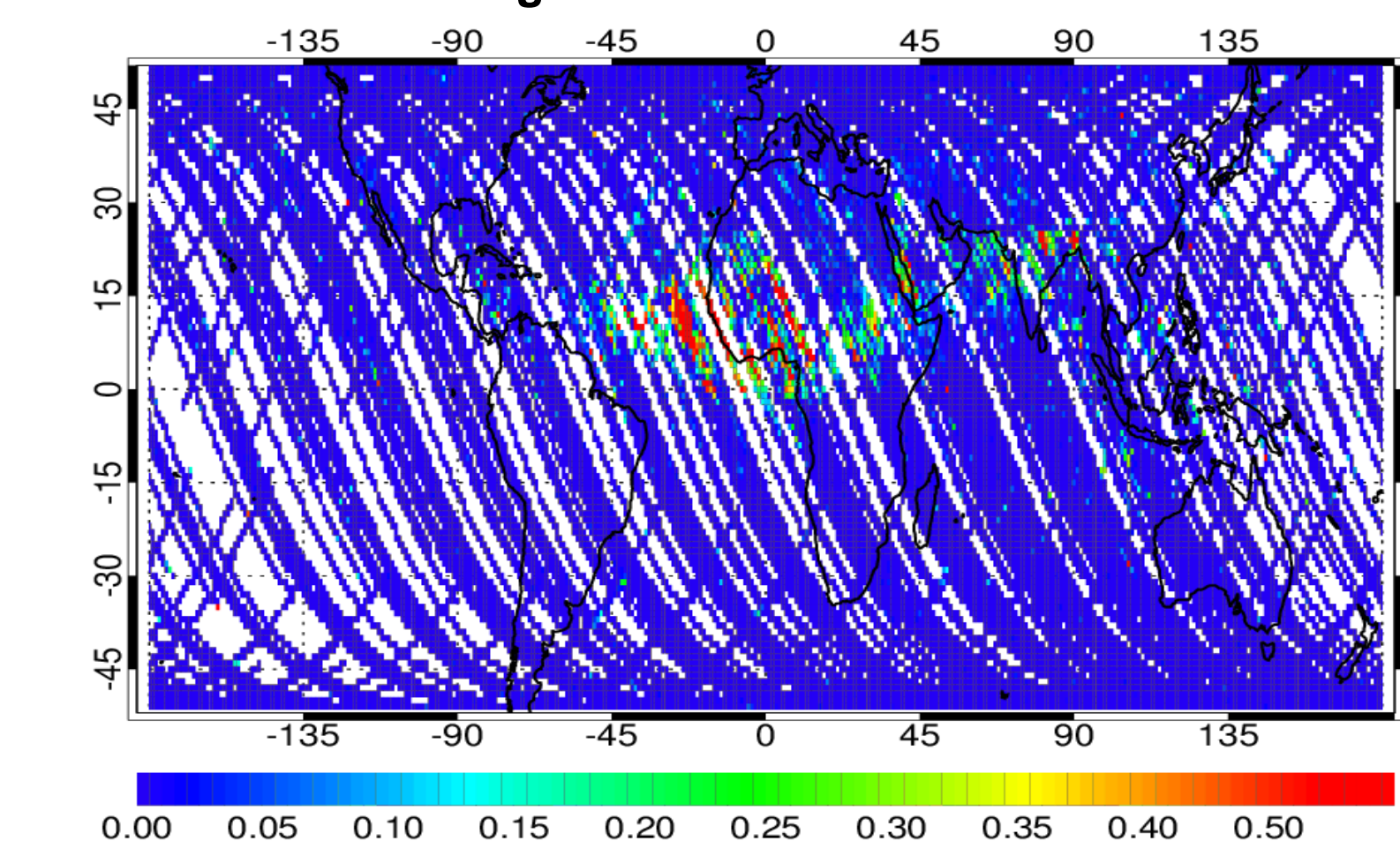CATS Version 2 August 2015 Dust Mixture AOT

Figure 2. CATS version 1 (top) and version 2 (bottom) August 2015 dust mixture AOT. Improved cloud – aerosol discrimination reduces the frequency of water clouds falsely identified as aerosol.

3. Updated Aerosol Typing Algorithm and Lidar Ratios

The CATS mode 2 version 1 aerosol typing algorithm was designed with similarity to the CALIPSO aerosol typing algorithm. Notable differences include CATS aerosol typing was performed at 1064 nm vs. 532 nm for CALIPSO and a refined elevated aerosol definition for improved smoke identification over marine layers based on Nowottnick et al. [2015]. The CATS mode 2 version 2 aerosol typing algorithm has several modifications to the version 1 algorithm, including:

- Reduction in dust & dust mixture depolarization ratio thresholds based on aerosol type comparisons with CALIPSO over south Asia
- Incorporation of a horizontal persistence test to reduce type "striping" in aerosol layers
- Utilization of GEOS-5 simulated aerosols to help discriminate polluted continental vs. smoke aerosol layers to permit polluted continental classification over water

CATS Version 2 Aerosol Typing Algorithm

CATS V2-00 1064 nm Lidar Ratios
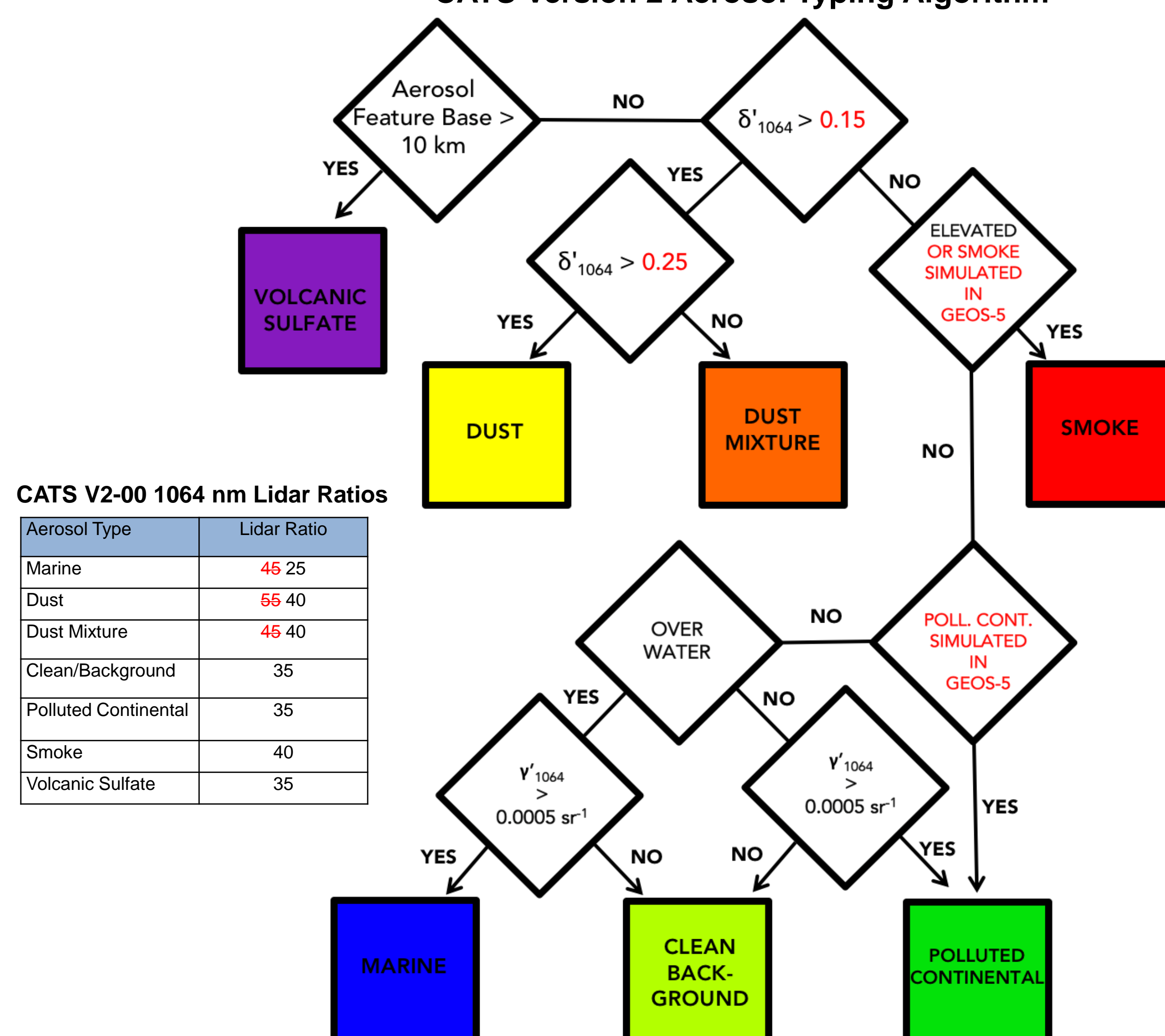
Aerosol Type	Lidar Ratio
Marine	45 25
Dust	55 40
Dust Mixture	45 40
Clean/Background	35
Polluted Continental	35
Smoke	40
Volcanic Sulfate	35

Figure 3. Updated CATS level 2 aerosol typing algorithm and lidar ratios. Changes to the version 1 algorithm are indicated in red. Modifications to CATS aerosol lidar ratios are based on CATS observations when the transmission-loss method could be used to determine the lidar ratio.

CATS 1064 nm Tot. Attenuated Bks.

CATS 1064 nm Depolarization Ratio

CATS Version 1 Aerosol Tying

CATS Version 2 Aerosol Typing

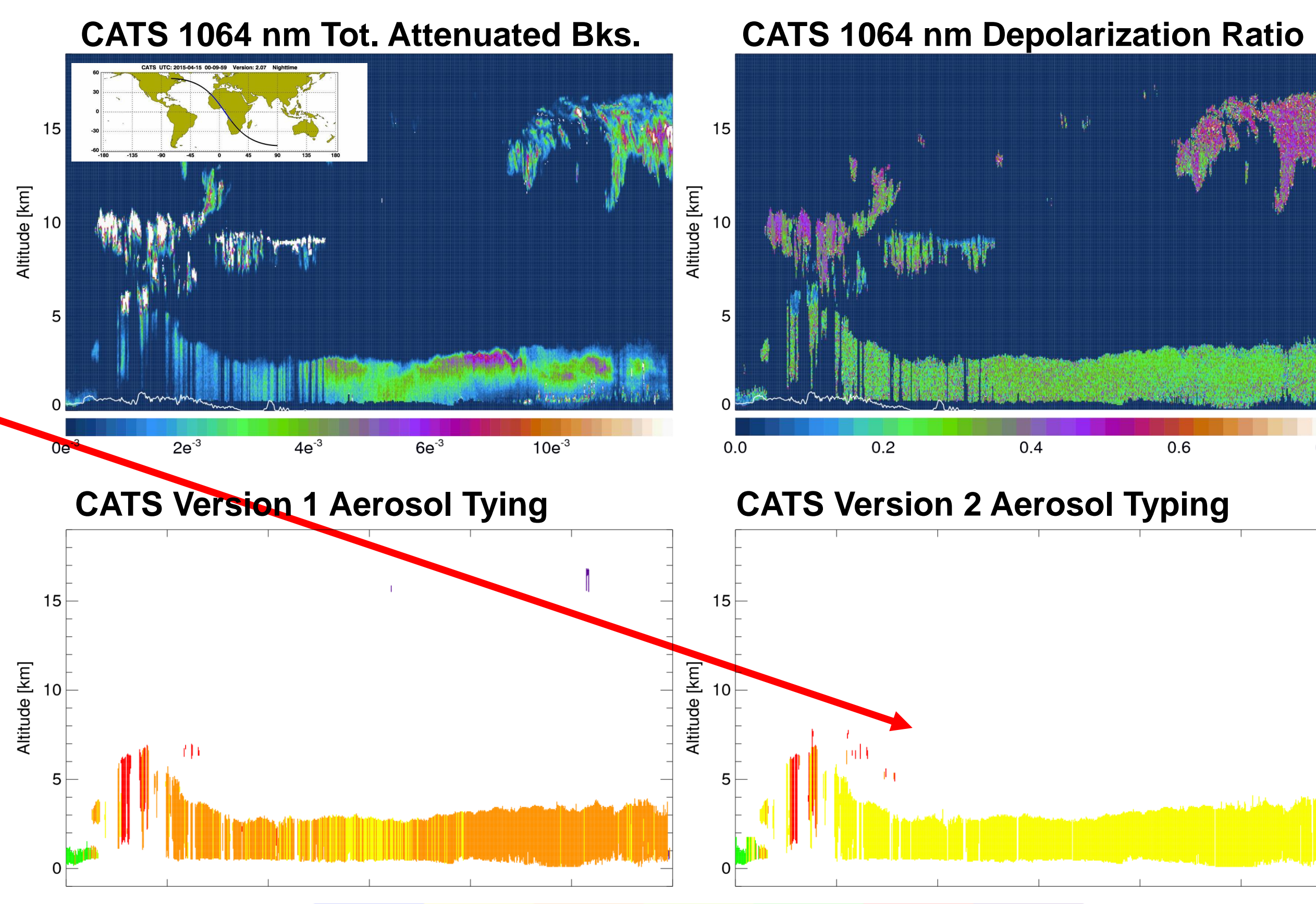MARINE   DUST   DUST MIXTURE   CLEAN   POLLUTED CONT.   SMOKE   VOLCANIC

Figure 4. CATS 1064 nm total attenuated backscatter (top left), depolarization ratio (top right), version 1 aerosol typing (bottom left), and version 2 aerosol typing (bottom right) for a dust layer on April 15, 2015.

CATS August 2015 Polluted Continental AOT
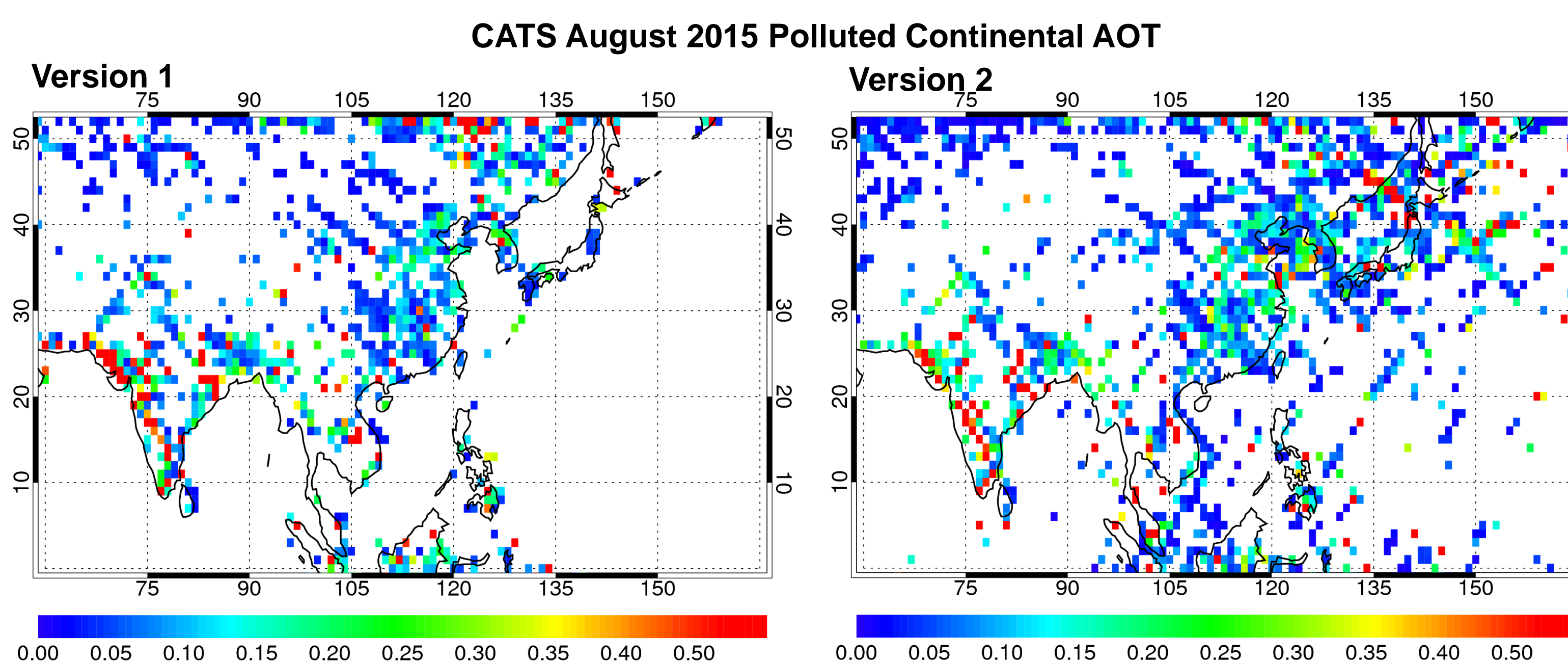

Version 1

Version 2

Figure 5. CATS version 1 (left) and version 2 (right) August 2015 polluted continental AOT. Classification of transported polluted continental aerosol over the ocean is the result of incorporating GEOS-5 simulated aerosols.

5. CATS NRT Data Applications

CATS NRT data products are available within 6 hours of data acquisition and include observed L1B data (total attenuated backscatter & depolarization ratio) and L2 vertical feature mask products. As a result, CATS NRT data has been used in the flight planning of several field campaigns.
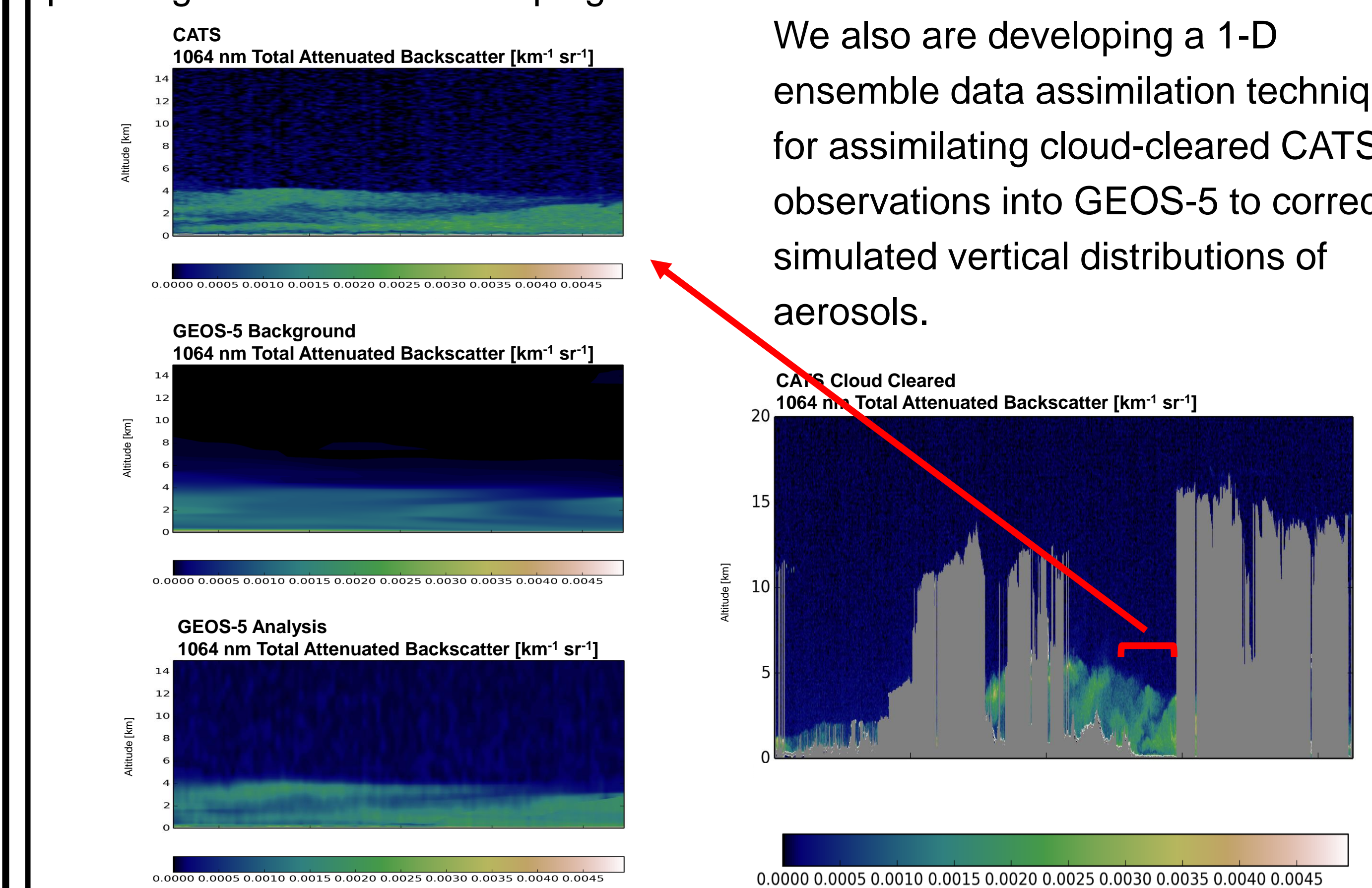
We also are developing a 1-D ensemble data assimilation technique for assimilating cloud-cleared CATS observations into GEOS-5 to correct simulated vertical distributions of aerosols.

CATS 1064 nm Total Attenuated Backscatter [km⁻¹ sr⁻¹]

GEOS-5 Background 1064 nm Total Attenuated Backscatter [km⁻¹ sr⁻¹]

GEOS-5 Analysis 1064 nm Total Attenuated Backscatter [km⁻¹ sr⁻¹]

CATS Cloud Cleared 1064 nm Total Attenuated Backscatter [km⁻¹ sr⁻¹]

Figure 6. CATS cloud-cleared total attenuated backscatter for a dust event over the Arabian Peninsula (right; top left), GEOS-5 background simulated total attenuated backscatter, and GEOS-5 analysis total attenuated backscatter after implementing our 1-D ensemble technique.

6. Summary

CATS continues to operate on the ISS providing high quality observations of clouds and aerosols. Our updated version 2 level 2 products will be released during summer 2017 and include:

- Improved cloud – aerosol discrimination
- An updated aerosol typing algorithm that utilizes GEOS-5 aerosols for classifying smoke and polluted continental aerosols

CATS NRT products are available for field campaign support and are being utilized to develop a 1-D ensemble assimilation technique in GEOS-5.