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Abstract
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CHIME Level 2A and 2B: Atmospheric Correction and Higher-Level Processing

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Challenge

CHIME (Copernicus Hyperspectral Imaging Mission for the Environment), planned to be launched in 2028, aims to complement the existing Copernicus satellites for observing land and coastal areas. The mission is synergetic with Sentinel-1, -2, -3 and LSTM, and also with other international hyperspectral missions such as SBG, EnMAP (by DLR) and PRISMA (by ASI).

The imaging spectrometer covers the visible, near and shortwave infra-red spectral range from 400 nm to 2500 nm at intervals of at most 10 nm and at spatial resolutions of at most 30 m. These Earth observation capabilities will in particular support services for food security, agriculture and raw materials.

Based on Top-Of-Atmosphere (TOA) radiances in cartographic or sensor geometry, Bottom-Of-Atmosphere (BOA) reflectance will be generated fulfilling the CEOS ARD surface and aquatic reflectance specifications. Also, a range of higher-level high priority products related to canopy & leaf level and soil & mineralogy will be provided.

Methodology

CHIME Level 2A and 2B processors will be provided as open source and integrated in the Copernicus Expansion Mission Product Algorithms Laboratory (CEM-PAL) and for Level 2A in ESA's operational processing environments for systematic product generation and distribution to users.

The CHIME Level 2A processor will use several features of PACO (Python-based Atmospheric COrrection), duly optimized for CHIME, and optimized atmospheric corrections for land and water surfaces. First, it masks pixels, e.g. land-water, cloud-haze-cirrus-clear. It then derives atmospheric parameters based on mission-external Copernicus Atmosphere Monitoring Service (CAMS) and mission-internal instrument data. Next, it determines the reflectance for all types of terrain using the Copernicus DEM and based on Look-

Up-Tables containing various atmospheric profiles and radiative transfers using libRadTran. Finally, the surface anisotropy quantified by Bidirectional Reflectance Distribution Function (BRDF) models is corrected.

The CHIME Level 2B processor will apply well-established approaches for the retrieval of Canopy and Leaf Nitrogen and Water Content, Leaf Mass per Area for vegetated pixels, and Soil Organic Carbon (SOC) content and Kaolinite abundance for non-vegetated pixels. Due to the influence of cover fractions of green photosynthetic active vegetation (PV), dry non-photosynthetic vegetation (NPV) and bare soil per pixel, these will be estimated by an improved and tailored pixel masking.

Results

To derive the atmospheric profile, air temperature and total ozone columns are extracted based on CAMS. Aerosol Optical Thickness (AOT) retrieval is based on dark reference areas in different wavelength ranges, e.g. 2100 nm, 660 nm, 470 nm for land and 850 nm, 660 nm for water, and especially in typical spectral relations. Water Vapour (WV) is estimated based on absorption regions at 945 nm, 1130 nm. Other molecular absorbers are expected to have constant mixing ratios.

Vegetation products are based on a hybrid model blending the physics described by coupled canopy-leaf radiative transfers related to multiple states of vegetation characteristics and the efficiency of machine learning regression algorithms. For SOC content products, first dominant soil pixels are selected and then a SOC reference soil database is used for the parametrization of the machine learning retrieval model. For kaolinite abundance products, first kaolinite-bearing pixels are selected and then the kaolinite abundance and uncertainty are determined using machine learning techniques.

The uncertainty analysis for the outputs considers the input uncertainties and uncertainty tree diagrams for the processing to account precisely for error contributors and to achieve consistency for Level 2A and 2B. Propagation is performed through analytical or Monte Carlo methods, depending on the applicability of assumptions on Gaussian probability distributions and linear measurement functions in the range of errors.

Outlook for the future

L2H/F (harmonized / fused) extends Level 2A processing based on CHIME and SBG Level 1C products by considering co-registration to a reference image, inter-calibration, and spectral band adjustment, to obtain denser (and longer) time series.

The realization of Level 2A and 2B processors will start by Q4/2023 and first prototypical versions are expected for Q4/2024 and Q2/2026, respectively, and final operational versions one year before CHIME satellite launch.

In particular after launch, the Calibration and Validation (Cal/Val) of Level 2A and 2B products will extensively consider uncertainty information to ensure the mission performs within specified limits and to verify the accuracy of the derived products, usually by comparing it to a reference standard traceable to the International System of Units (SI) or to other internationally accepted standards and to independent ground-based measurements, e.g. RadCalNet and AERONET, or other mission products like NASA SBG and ESA TRUTH.

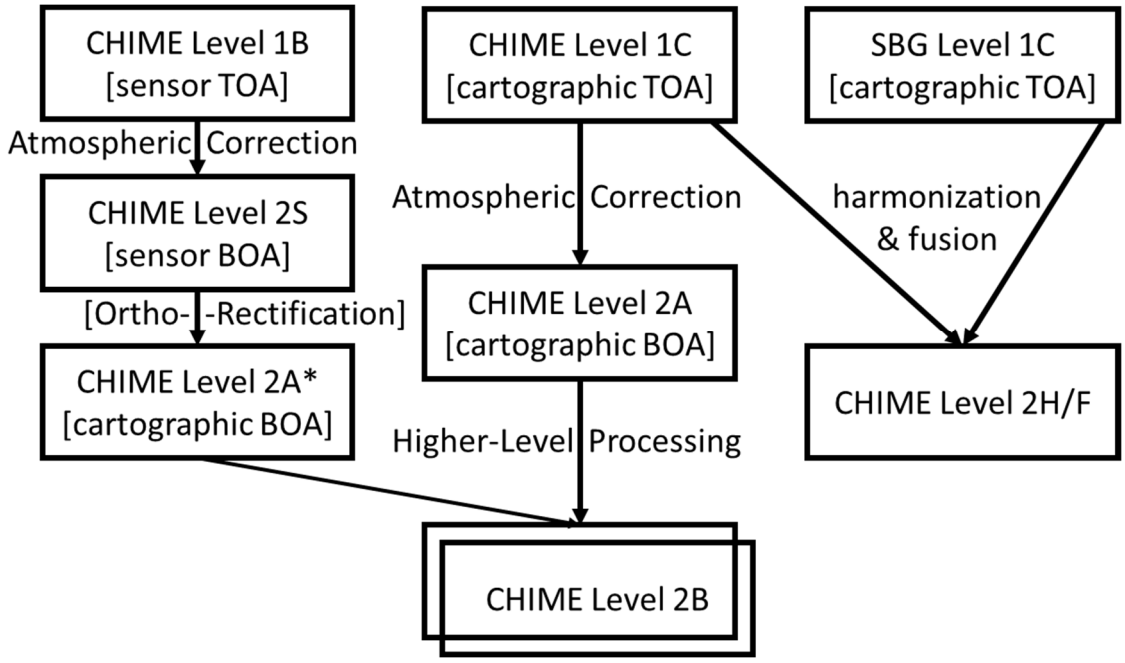

Figure Illustration of Product Levels