PACE HARP2 V4 Processing Notes

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HARP2 Level-1A/B/C Data

The Version 4 (V4) release of HARP2 Level-1 data represents a comprehensive refinement of the instrument's radiometric, polarimetric, and geometric performance from V3. The version integrates over two years of on-orbit performance data, utilizing Solar/lunar calibrations, Earth-view flatfield and alignment calibrations, and vicarious trending calibrations to address CCD degradation and radiometric drift. Key improvements include pixel-level detector alignment, refined intensity and polarization accuracy, and improved geolocation.

Changes from Version 3 include:

Radiometric Calibration Updates

- Flatfield Refinement: Transitioned from dynamic Solar Cal to a hybrid Pre-launch Lab + Dynamic Earth-view calibration model.
- Stray-Light optimization: Improved stray-light coefficients for far-view angles and corrected issues related to detector cross-track binning.
- Degradation Trending: Implemented a trending correction for radiometric gain for each sensor, as characterized from Solar and Lunar calibration and ground-based vicarious calibration analysis.
- OCI Cross-Calibration: Updated radiometric coefficients by matching signal response with OCI to ensure multi-sensor data consistency.

Polarimetric Improvements

- False Polarization: Replaced the V3 detector-level shift with "pixel-level" detector alignment corrections based on on-orbit alignment calibrations, leading substantial reduction of false polarization for feature-rich targets (such as cloud, coast lines, etc.).
- Polarization Accuracy
    - Improved the accuracy of Degree of Linear Polarization (DoLP) from the flatfield refinement.
    - Improved accuracy of the Stokes Q and U components and the Angle of Linear Polarization (AoLP) by correcting polarization reference plane rotation from the instrument plane to the view meridian plane.

Geolocation and Geometric Improvements

- Cameral Optical Model and Geolocation: Updated camera geometry for HARP2 science image with correct onboard binning implementation, refined optical distortion model using full-resolution captures, and optimized boresight offsets. These updates improved HARP2 multi-angular geolocations, especially for far-view angles.
- Improved accuracy of sensor zenith angles over high-relief areas from a bug fix in the terrain correction.

Known Issues:

- Vertical fringes, although significantly reduced by refined flatfield in V4, still exist in the polarization (i.e., Q, U, and DoLP) pushbrooms for some view angles. These are mainly driven by flatfield variations. Further fringe characterization is an ongoing effort, and corrections will be applied in a later version.
- Error in geolocation still exists, which can exceed 1 pixel for far angles (over 50 degrees. There are also evidence showing a temporal geolocation drift. Refinement of optical distortion and correction of geolocation drift are ongoing efforts, and further sub-pixel improvements are expected in a later version.

HARP2 Level-2 Products

MAPOL_LAND (Aerosol and Land Properties, FastMAPOL Algorithm)
MAPOL_OCEAN (Aerosol and Ocean Properties, FastMAPOL Algorithm)

Changes from Version 3:

- Uses Version 4 L1C data, with the same FastMAPOL retrieval algorithm previously applied to Version 3 data.
- Aerosol retrieval quality is improved for the MAPOL_OCEAN data suites. Quality flags 0 and 1 are recommended for scientific applications.
- Quality flag definitions have been updated. Please refer to the new HelpHub notebooks for details:

https://nasa.github.io/oceandata-notebooks/sections/cloud-atmosphere.html

- Ocean surface reflectance products Rrs1 and Rrs2 have been renamed Rrs_angular and Rrs_nadir, respectively. These represent angular Rrs before and after BRDF correction.
- New MAPOL_LAND data suites have been added. Multi-angle land surface reflectance is reported as rhos_angular and rhos_nadir.

Known issues:

- For MAPOL_OCEAN data, a large fraction of aerosol retrievals is still associated with lower-quality retrieval conditions, including larger χ^2 values and fewer valid viewing angles (nv_ref and nv_dolp). These retrievals can exhibit larger biases in aerosol optical properties such as AOD. Users are encouraged to apply the recommended quality flags.
- MAPOL_LAND is undergoing active testing and improvement. The current version shows significant biases in both fine- and coarse-mode aerosol properties and should therefore be used with caution.

CLOUD_GPC (Cloud Properties from GISS Polarimetric Cloud Algorithm)

Changes from Version 3:

- Improvements in Level-1A/B/C polarization measurements now enable retrievals that were previously missing over the lower-right portion of the granule
- Some droplet size distribution retrievals that previously exceeded the theoretical limits now show more reasonable values.

Known issues:

- Some unrealistic droplet size distribution retrievals are still flagged as “valid”. An improved flagging mechanism is under development.

HARP2 Level-3 Products

HARP2 Level-2 products are composited into global Level-3 binned and mapped products. Daily, 8-day, and monthly Level-3 mapped products are produced on an equirectangular grid at 0.1-deg and 1-deg resolution. The available list of mapped product types now include:

- MAPOL_OCEAN: aerosol and ocean properties from FastMAPOL algorithm
- MAPOL_LAND: aerosol and land properties from FastMAPOL algorithm
- CLOUD_GPC: cloud properties from GPC algorithm

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HARP2 Level-1A/B/C Data (Provisional)

On-orbit calibration data has been collected during solar and lunar calibration exercises, and a refined calibration is included in the version 3 release.

Changes from Version 2:

- For Level-1A data products, removed a x2 scaling to the AST4 (i.e., science acquisition) detector counts that was used in previous Level -1A versions, so that the detector count values are consistent across different HARP2 operations modes (i.e., between calibration and science).
- Updated radiometric coefficients, spectral center/FWHM, non-linear correction, based on a refined pre-launch calibration.
- Improved pixel defect masking to reduce vertical stripes in pushbroom images.
- Polarimetric calibration matrices (used for determining polarization from HARP2's three sensors) are expanded to full detector, whereas detector center characterization was used in previous versions. This change improves the polarization accuracy for off-nadir views.
- Improved stray light correction for off-nadir views based on extended analysis on the pre-lunch calibration.
- Applied dynamic flatfield and dark corrections based on frequent onboard solar and dark calibration, which replaced the static dark/flatfield onboard calibration characterized at beginning of the mission.
- Improved geolocation and multi-view co-registration.

Known issues

- Vertical fringes exist in the polarization (i.e., Q, U, and DoLP) pushbrooms for some view angles. These are mainly driven by uncertainty in detector flatfield (<1%).
- A geometrical-dependent bias of polarization exists in large view (zenith angle over 50 degrees from space). This is potentially caused by inaccurate stray-light correction and/or complex view-dependent polarimetric calibration at the edge of the detectors.
- Some level of false polarization due to imperfect detector alignment with current correction, which are more noticeable in nadir views.
- Error in geolocation still exists for far angles (over 50 degrees), which can exceed 1 pixel.

HARP2 Level-2 Products

MAPOL_OCEAN (Aerosol and Ocean Properties from FastMAPOL Algorithm)

This is the first release of Level-2 and Level-3 products from the FastMAPOL algorithm as applied to HARP2 Version 3 Level-1C. The FastMAPOL algorithm generates a large suite of aerosol and ocean optical properties. A subset is listed here.

Provisional Products

- Aerosol Optical Thickness (aot)
- Single Scattering Albedo (ssa)
- Effective Radius of Fine Mode Aerosols (reff_fine)
- Effective Radius of Coarse Mode Aerosols (reff_coarse)
- Fine Mode Fraction (fmf)
- Fine Mode Fraction by Volume (fvf)
- Real Index of Refraction (mr)
- Imaginary Index of Refraction (mi)
- Wind speed (wind_speed)
- Chlorophyll a concentration (Chla)
- Angular Remote Sensing Reflectance before BRDF correction (Rrs1)
- Angular Remote Sensing Reflectance after BRDF correction (Rrs2)

Known issues

- Aerosol optical depth is biased high (~0.07) as compared with AERONET-OC.
- Remote-sensing reflectance (Rrs) is biased low (-0.001) as compared with AERONET-OC.
- High uncertainty in aerosol microphysical retrievals (mr, mi, sph, alh etc).
- Fewer polarization measurements than radiance measurements are successfully fitted, as indicated by valid angle counts (Nv_ref and Nv_dolp) and angular data mask (mask_ref and mask_dolp).

CLOUD_GPC (Cloud Properties from GISS Polarimetric Cloud Algorithm)

This is the first release of Level-2 and Level-3 products from the GISS Polarimetric Cloud (GPC) algorithm, applied to HARP2 Version 3 Level-1C. The GPC algorithm produces a suite of cloud properties using three polarimetric cloud retrievals techniques, along with additional cloud properties derived by combining them with selected OCI L2 CLD retrievals. Selected additional variables from OCI L2 CLD are also included. A subset is listed here.

Provisional Products

- cloud_bow_droplet_effective_radius
- cloud_bow_droplet_effective_variance
- cloud_bow_rms

- cloud_bow_fit_correlation
- cloud_bow_quality_retrieval_fail
- cloud_liquid_index
- cloud_rft_mode_fraction_0
- cloud_rft_mode_fraction_1
- cloud_rft_quality_retrieval_fail

Known issues

- Retrieval artifacts associated with L1C polarization—particularly those related to rotation plane and angle—are present but are expected to improve as the L1C polarization calibration effort progresses.
- Early versions of RFT retrievals are intended primarily for exploratory purposes to support algorithm refinement. Larger biases and other issues are expected in RFT retrievals compared to parametric retrievals.

HARP2 Level-3 Products

HARP2 Level-2 products are composited into global Level-3 binned and mapped products. Daily, 8-day, and monthly Level-3 mapped products are produced on an equirectanular grid at 0.1-deg and 1-deg resolution. The available list of mapped product types now include:

- MAPOL_OCEAN: aerosol and ocean properties over ocean from FastMAPOL algorithm
- MAPOL_LAND: aerosol and land properties over ocean from FastMAPOL algorithm
- CLOUD_GPC: cloud properties from GPC algorithm