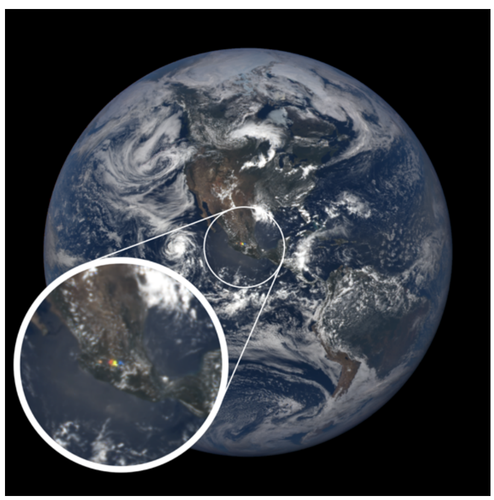
VERSION 1 LEVEL 2 EPIC SUN GLINT PRODUCT:

USER GUIDE



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Tamás Várnai[1,2], Alexander Marshak[1], Alexander Kostinski[3]

[1]NASA Goddard Space Flight Center, [2]University of Maryland Baltimore County,

[3]Michigan Technological University

Table of contents

1. Spacecraft and Instrument 1
2. Sun Glint Detection Algorithm..2
3. Level 2 Sun Glint Product File..5
References 7

This document was created in support of the DSCOVR mission.

1. Spacecraft and Instrument

This document describes the sun glint data product of the Earth Polychromatic Camera (EPIC) onboard the Deep Space Climate Observatory (DSCOVR) spacecraft.

DSCOVR was launched on February 11, 2015, and arrived to the Sun-Earth L1 Lagrangian point on June 8, 2015. This point lies near the straight line connecting the Sun and Earth and thus allows DSCOVR instruments to observe the sunlit side of Earth from an almost backscattering direction. DSCOVR is about one-and-a-half million kilometers from Earth—in other words, it is about four times farther than the Moon.

EPIC started providing observations on June 13, 2015. Since then, it typically provides 22 images a day between April and early September, and 13 images a day during the rest of the year. The number of images is smaller from April to September because DSCOVR can transmit less data, as the ground communication station (located at the NASA Wallops Flight Facility in Virginia, USA) is visible from DSCOVR for shorter times during the shorter days.

EPIC uses a spectral filter wheel to take images at 10 wavelengths ranging from 317 to 780 nm. The images at different wavelengths are taken within a roughly 7-minute-long period as the filter wheel cycles through all wavelengths. Importantly for the glint product, the 551 nm (green), 680 nm (red), and 388 nm (UV) images are taken about 3, 4, and 6 minutes after the 443 nm (blue) images, respectively. The spatial resolution of EPIC images is around 8 km at the image center and decreases toward the edge of the Earth disk, though the exact resolution increases or decreases slightly when DSCOVR moves slightly closer or farther from Earth.

The EPIC team provides operational data products to the public through the Atmospheric Science Data Center (ASDC) of the NASA Langley Research Center (https://search.earthdata.nasa.gov). The freely available products include calibrated and geolocated reflectances as well as various characteristics of land surfaces, oceans, and the atmosphere.

Details about DSCOVR, EPIC, and its data products can be found in Marshak et al. [2018] and at the EPIC website (https://epic.gsfc.nasa.gov). The EPIC website also includes a list of publications (https://epic.gsfc.nasa.gov/science/pubs) about scientific studies using EPIC data, true-color renderings of all available EPIC images, plus galleries of several data products and some remarkable observations, and even a few photos of the DSCOVR spacecraft and the EPIC instrument itself.

2. Sun Glint Detection Algorithm

The key, central component of the EPIC Level 2 operational sun glint product is the glint mask. This mask identifies the image pixels where the observed EPIC Level 1B reflectance values are significantly affected by sun glint—that is, by the strong specular reflection of sunlight from horizontal surfaces. The focus of the glint product is to detect glints from horizontally oriented ice crystals occurring in clouds and from smooth water surfaces. Studying such glints (e.g., Li et al., 2019; Kostinski et al., 2021, 2024, 2026; Zhou et al., 2021) can help, among others, learn about ice clouds (e.g., Várnai et al., 2020a, 2020b; Kostinski et al., 2026) or to understand the problems these glints can cause in satellite retrievals of atmospheric properties (e.g., Várnai et al., 2024). In contrast, the glint product does not seek to identify diffuse glints from rough ocean surfaces. The glint product contains individual glint masks for three EPIC bands: 443 nm (blue), 551 nm (green), and 680 nm (red); no glint mask is produced for the other 7 bands.

We note that glints from ice cloud crystals or smooth water surfaces can occur only in small portions of EPIC images, and so the glint masks contain fill values outside a small, roughly 100 km by 100 km size area. This is because, due to Earth's curvature, the direction of specular reflection changes with location, which implies that specular reflection from horizontal surfaces can be observed by EPIC only in a small region centered on the so-called "specular spot" (Figure 1). As discussed in Marshak et al. (2017), the location of specular spots drifts with the seasons between about 25° North in June and 25° South in December.

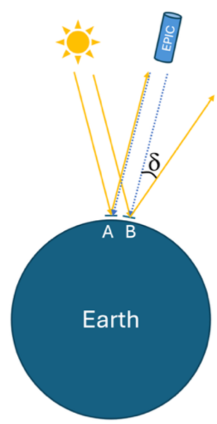

Figure 1. *Illustration of specular reflection from horizontally oriented ice crystals in clouds. Yellow solid lines represent sunlight, and blue dotted lines represent the EPIC view direction. The glint angle (δ) is the angle between the direction of specularly reflected light and the view direction. Point A is at the specular spot, where δ=0 and EPIC can view specular reflection. Due to the curvature of Earth, specular reflection from clouds at point B goes to a different direction and cannot be observed by EPIC.*

The glint mask is produced by a glint detection algorithm that works by comparing two EPIC images of the same scene. One is the image in which we seek to identify glints, and the other is a "reference image" that we use to estimate what the scene could look like in the absence of glints. Glints are then reported if there is a large difference between the observed image and our "glintless reflectance estimate" based on the reference image.

The pairs of images used for glint detection constitute of two EPIC images taken at different wavelengths. As mentioned in Section 1, EPIC uses a filter wheel to obtain images at 10 wavelengths within a few minutes of each other. For example, the 388 nm ultraviolet (UV) images are taken about 5 min after blue images. During these 5 minutes, the rotation of Earth changes the vertical direction at the observed scenes by 1.25°. Following the law of reflection, a 1.25° change in the orientation of a reflector will change the direction of specularly reflected light by 2.5°. As the position of DSCOVR and hence the view direction of EPIC does not change significantly in 5 minutes, and as glints from clouds or smooth water are only about 1° wide, the 2.5° change in the direction of specularly reflected light means that a glint observed at 443 nm will not affect the image taken 5 minutes later at 388 nm. Thus, the 388 nm image can serve as "reference image" for detecting glints in the blue image.

When trying to detect glints affecting green or red images, the algorithm uses the blue image as the glint-free reference image. This works because blue images are taken 3 and 4 minutes before the green and red images, respectively—hence it will not contain glints around the specular spots of green or red images. We note that, due to the rotation of Earth, glints in the red images appear roughly 100 km to the west from glints in the blue images, with glints in the green images appearing in between (Figure 2).

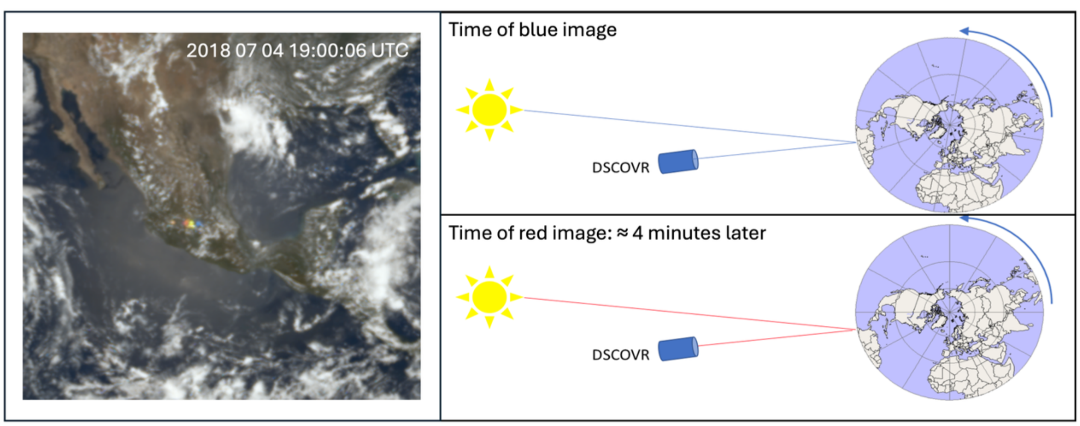

Figure 2: *(Left) An EPIC image illustrating that red glints appear about 100 km to the west of blue glints, with green glints appearing in between. Areas where both red and green images are affected by glint appear yellow in RGB natural color composite images. (Right) Schematic illustration of why the rotation of Earth between the capture of blue and red images results in red and green glints appearing to the west of blue glints.*

A key part of glint detection is the selection of reflectance thresholds used for glint detection. For example, a pixel in a blue image is deemed glint-affected if $R_{443nm} > R^*(R'_{388nm})$ and is deemed glint free otherwise. In this formula, R_{443nm} is the 443 nm reflectance observed at the pixel and R^* is the glint detection threshold, which depends on R'_{388nm}, the maximum 388 nm reflectance in a 3X3 pixel area centered around the pixel. The 3X3 maximum is used in order to avoid false glint detections when clouds that are just outside a pixel in the UV image appear inside the pixel in the blue image because of wind drift, cloud growth, or differences in the exact location of pixel boundaries in the blue and UV images. We note that glint detections work the same way for red and green images, except for using the blue (and not the UV) image as the reference image.

As described in Várnai et al. (2021), the R^* threshold values for each possible R'_{388nm} were determined through the statistical analysis of all EPIC images taken in 2018. By considering areas that are just far enough from the specular spot so they cannot be affected by cloud glint, the analysis determined the distribution of glint-free R_{443nm} values for each R'_{388nm}—and then chose such R^* values that R_{443nm} was 10 times more likely to exceed them around the specular spot (where glints may be seen) than in regions that are slightly farther from the specular spot (and thus cannot be affected by glint). This ensured a 90% accuracy for glint detections—that is, it ensured that in 90% of pixels identified as “glint”, the threshold is exceeded due to specular reflection and not due to unrelated factors such as clouds drifting with the wind. We note that while choosing higher threshold values would have reduced the number of false detections, it would have also left more faint glints undetected.

The operational algorithm uses the same process for the blue, green, and red image glint detections, with the only difference being in the spectral bands used. (As mentioned earlier, we use 388, 443, and 443 nm images as reference images for the detection of blue, green, and red glints, respectively). If we use glint detections in blue (443 nm) images as an example, the main steps of this process can be listed as follows:

- Skip EPIC images if data for any of the bands used by the glint detection algorithm (388, 443, 551, or 680 nm) is missing. Otherwise proceed to the next steps to examine each image pixel one-by-one.
- Calculate the glint angle for each pixel in the blue image using the pixel’s solar and viewing zenith and azimuth angle values provided in the Level 1B reflectance product.
- Set the pixel’s blue glint mask value to a fill value (-999) if $\delta_{443nm} > 2°$, or if $\delta_{443nm} > \delta_{388nm}$. This occurs if the distance from the specular point (where $\delta_{443nm} = 0°$) exceeds about 100 km. Otherwise, proceed to the next step.
- Identify the pixel’s surface type based on its coordinates and a global map of surface types. This map was created based on the MCD12C1 surface cover product of the

Moderate Resolution Imaging Spectroradiometer (MODIS) instrument (DOI: 10.5067/MODIS/MCD12C1.006). The map used for glint detection reduces the original set of surface types provided by MODIS to just three types: water, desert, and vegetated land (which encompasses all non-desert land). The surface type is determined because different R^* thresholds are used for each type.

- Calculate R'_{388nm} as the maximum 388 nm reflectance in the 3X3-pixel area around the pixel.
- Based on the surface type and R'_{388nm}, select the applicable R^* glint detection threshold value.
- Flag the pixel as glint if $R_{443nm} > R^*$, or as non-glint if $R_{443nm} \leq R^*$.

A detailed description of the glint detection method, accompanied by examples and statistics of glint detection results, can be found in Várnai et al. (2021).

3. Level 2 Sun Glint Product File

The EPIC Level 2 operational sun glint product is available for the entire duration of the DSCOVR mission, starting with June 13, 2015. A separate glint product file is produced for each EPIC image for which Level 1B data is available at all spectral bands used for glint detection: 388, 443, 551, and 680 nm.

The glint product is provided in a separate HDF5 file for each EPIC image. (HDF5 is a common file format that is identical to NetCDF4.) The filename contains the product version (01) and collection version (03), as well as the date and time of capturing the EPIC 780 nm image. For example, for the image captured on August 1, 2023 at 04:58:23 UTC, the glint product filename is DSCOVR_EPIC_L2_GLINT_01_20230801045823_03.h5.

The typical file size of the glint product is about 4.1 MB for each EPIC image. The file size is relatively small because glint detection is performed only in roughly 100 by 100 km areas, and all data fields in the glint product files are set to the fill value of -999 outside this area. This is especially helpful as data compression can dramatically reduce the amount of data needed to store the fill values outside this area. The operational processing uses the “lzf” compression algorithm, which produces files that can be decompressed quickly and easily. For example, people using python codes do not even have to specify that the files are compressed: Standard Python automatically recognizes the need for decompression and performs it quickly without any prompting by the user (no library installations or decompression statements are required).

The glint product files contain 9 separate data fields, listed in Table 1.

Name	Dimensions
latitude*	nCol, nRow
longitude*	nCol, nRow
solarZenithAngle*	nBand, nCol, nRow
solarAzimuthAngle*	nBand, nCol, nRow
viewZenithAngle*	nBand, nCol, nRow
viewAzimuthAngle*	nBand, nCol, nRow
surfaceType	nCol, nRow
glintAngle	nBand, nCol, nRow
glintMask	nBand, nCol, nRow

Table 3. *Datasets included in the EPIC Level 2 sun glint product files. The datasets marked with an asterisk are part of the product file only for images taken after January 1, 2022. For earlier dates, these datasets can be found in other EPIC products such as Level 1B product or the Level 2 cloud product. (Pixels in those products match the pixels in the glint product.)*

All datasets contain separate values for each EPIC pixel. Since EPIC images contain 2048 rows and 2048 columns, nRow = 2048 and nCol = 2048 in all glint files. The first column represents the western edge of the EPIC image; the first row represents the northern edge.

Some of the parameters are provided for three EPIC bands, hence nBand = 3. In the glint product files, the first band is 443 nm, the second is 551 nm, the third is 680 nm.

We note that the latitude, longitude, and surface type is identical for all EPIC bands, hence these three datasets are two-dimensional (rows and columns) and lack the third dimension that could identify EPIC bands.

Except for surface type and glint mask, all values are provided in units of degree. The surface type can take four possible values: -999: Fill value, 0: Water, 1: Non-desert land, 2: Desert. The glint mask can take three possible values: -999: Fill value, 0: No glint, 1: Glint.

Detailed explanations about the glint product file and about each individual dataset are also included into the product files themselves as file or dataset attributes.

A sample python code to read data and attributes from the glint product file is provided below.

```
# Import necessary libraries
import h5py
import numpy as np

# Open input file
f = h5py.File('DSCOVR_EPIC_L2_GLINT_01_20230801045823_03.h5', 'r')

# Print the overall file attributes
for k in f.attrs.keys():
   print('File attribute name:', k)
   print('File attribute value:', f.attrs[k])
print(' ')

# List datasets in file
print('Datasets in file:')
f.visit(print)
print(' ')

# Read a specified dataset, print its attributes and its maximum data value
dataSet = f['glintAngle']

print('Dataset attributes:')
for k in dataSet.attrs.keys():
   print(k)
   print(dataSet.attrs[k])

data = dataSet[:]
print('Maximum value in dataset:', np.max(data))
print(' ')

# Close input file
f.close()
```

References

Kostinski, A., A. Marshak, and T. Várnai, 2021: Deep space observations of terrestrial glitter, *Earth and Space Science*, **8**, e2020EA001521, doi: 10.1029/2020EA001521.

Kostinski, A., A. Marshak, and T. Várnai, 2024: Deep space observations of conditionally averaged global reflectance patterns, *Frontiers Remote Sens.,* **5**, doi: 10.3389/frsen.2024.1404461.

Kostinski, A., A. Marshak, and T. Várnai, 2026: Constraining orientation statistics of ice crystals in clouds with observations from deep space. *Front. Remote Sens.*, **6**, 1705235. doi: 10.3389/frsen.2025.1705235.

Li, J.-Z., S. Fan, P. Kopparla, C. Liu, J. Jiang, V. Natraj, and Y. Yung, 2019: Study of terrestrial glints based on DSCOVR observations. *Earth and Space Sci*., **6**, 166–173, doi: 10.1029/2018EA000509.

Marshak, A. et al., 2018: Earth observations from DSCOVR EPIC instrument. *Bull. Amer. Meteorol. Soc.,* **99**, 1829–1850, doi: 10.1175/bams-d-17-0223.1.

Marshak, A., T. Várnai, and A. Kostinski, 2017: Terrestrial glint seen from deep space: oriented ice crystals detected from the Lagrangian point. *Geophys. Res. Lett*., **44**, doi: 10.1002/2017GL073248.

Várnai, T., A. Marshak, and A. Kostinski, 2020: Deep space observations of cloud glints: Spectral and seasonal dependence. *IEEE Geosci. Rem. Sens. Lett.*, **19**, doi: 10.1109/LGRS.2020.3040144.

Várnai, T., A. Kostinski, and A. Marshak, 2020: Deep space observations of sun glints from marine ice clouds. *IEEE Geosci. Rem. Sens. Lett.*, **17**, doi: 10.1109/LGRS.2019.2930866.

Várnai, T., A. Marshak, and A. Kostinski, 2021: Operational detection of sun glints in DSCOVR EPIC images. *Frontiers Remote Sens*., **2**, 777806. doi: 10.3389/frsen.2021.777806.

Várnai, T., A. Marshak, A. Kostinski, Y. Yang, and Y. Zhou, 2024: Impact of sun glint off ice clouds on DSCOVR EPIC cloud products. *IEEE Trans. Geosci. Remote Sens*., **62**, 1-11, doi: 10.1109/TGRS.2024.3400253.

Várnai T., A. Marshak, and A. Kostinski, 2026: Statistics of glinting clouds observed by DSCOVR and geostationary satellites. *Frontiers Remote Sens*., **6**, 1696519, doi: 10.3389/frsen.2025.1696519.

Zhou, Y., Y. Yang, P. Zhai, and M. Gao, 2021: Cloud detection over sunglint regions with observations from the Earth Polychromatic Imaging Camera (EPIC), *Frontiers Remote Sens*., **2**, doi: 10.3389/frsen.2021.690010.