Abstract

Measured backscattered UV radiances at 388±1.5 nm, which are converted to Lambert Equivalent Reflectivity (LER), are from EPIC (Earth Polychromatic Imaging Camera) onboard the DSCOVR spacecraft (Deep Space Climate Observatory) orbiting about the Sun-Earth Lagrange-1 (L1) gravitational balance point. The non-repeating tilted Lissajous orbit about L1 has time varying backscatter angles BA in the Earth’s atmosphere that varied between 176O to 174O during 2015 to 2019 and increased to near BA = 178O in 2020 and 2021. Previous studies showed that backscattering from the Earth’s surface in the visible and near infrared wavelengths increases at high backscatter angles. Backscattering from land and oceans at 388 nm is small, since the average clear-sky reflectivity of the Earth’s surface free of snow and ice is about 0.05. Maximum reflected 388±1.5 nm solar energy, RSE, mostly from clouds, occurs during summer solstice in each hemisphere, December in the Southern Hemisphere SH and June in the Northern Hemisphere NH. The purpose of this study is to show that the observed increase in 388±1.5 nm LER in the summer months represents increased cloud amounts even when the backscatter angle gets close to 178O.

In the SH, calculations of RSE based on the 388±1.5 nm LER show an increased percent difference PD =7% during December 2020 at 40OS to 50OS when BA = 178.05O, and 6% at 30OS to 40OS in November 2021 when BA = 177.5O compared to previous years, 2015-2019. However, In the NH RSE values at large EPIC BA show a decreased PD(30ON to 60ON) = -3.6% at 40ON to 50ON during June 2021 when BA = 178.2O and a 6% increase during June 2020 at 50ON to 60ON with a smaller BA = 177.5O compared to the previous 4 years. The lack of enhanced backscatter in June 2020 suggests that the increase and decrease in RSE are mostly related to changes in cloud cover and not backscatter angle effects. The global annual integral of reflected 388±1.5 nm energy from clouds is almost constant for the period 2015 to 2020 at 29.2% of the incident solar irradiance.

Comparison of 380 nm RSE at 40OS to 50OS during December 2020 from the low Earth polar orbiting nadir mapper in the Ozone Mapping and Profiler Suite (OMPS-NM) near 13:30 local solar time suggests that there has been a 5% increase in SH cloud reflection during December 2020 compared to previous years. This confirms that EPIC’s observed increase in 388±1.5 nm RSE is mostly from an increase in cloud cover and not from enhanced cloud backscatter.

1.0 Introduction

The EPIC satellite instrument (Earth Polychromatic Imaging Camera) onboard the DSCOVR (Deep Space Climate Observatory) observed almost the full illuminated Earth’s disk since June 2015 from an orbital position near the Earth-Sun L1 point (Lagrange-1 point) approximately 1.5x106 km from the Earth. The spacecraft orbit consists of an approximately 6-month non-repeating tilted Lissajous figure about L1 that varies in distance from the Earth (±1x105 km). The changing orbit also causes variations in the instrument’s small satellite viewing angle from the Sun-Earth line (SEV) (Marshak et al., 2021). Recently (2020-2021), the SEV minimum has decreased from 4O – 6O to slightly less than 2O (backscatter angle BA = 178O, SEV= 180O - BA), which can cause the observation of reflected radiances to increase compared to observations from smaller backscattering angles (Marshak et al., 2021, Penttila et al., 2021). For EPIC, the largest enhanced backscatter effects for small SEV arise in the red and Near IR (NIR) bands from vegetation with smaller effects from clouds in the visible and NIR (Marshak et al., 2021). The purpose of this paper is to see whether a similar backscatter effect is seen in the UV from clouds in the absence of Earth surface effects.

The EPIC instrument observes the sunlit Earth using 10 narrow band filter channels from 317.5 nm to 780 nm (317.5, 325, 340, 388, 443, 551, 680, 688, 764, and 780 nm) using a 30-cm aperture telescope imaging on a 2048x2048 hafnium coated CCD (Charge Coupled Detector) with a field of view of 0.62O viewing the Sun illuminated Earth with a nominal angular size of 0.5O. Instrument details and calibration are discussed in Herman et al. (2018a) and Marshak et al. (2018). EPIC obtains between 13 to 22 images per 24 hours depending on the amount of time during a day that the receiving antenna at Wallops Island, Virginia (38ON latitude) is in view of the spacecraft. Measured backscattered UV radiances at 388±1.5 nm are converted to Lambert Equivalent Reflectivity (LER) as a function of latitude, longitude, and time (Herman et al. 2018a). LER(Latitude, Longitude) is the reflectivity of the Earth as a Lambertian surface after Rayleigh scattering is removed.

The Ozone Mapping and Profiler Suite (OMPS) onboard the joint NASA/NOAA Suomi National Polar-orbiting Partnership ([Suomi NPP](https://www.nasa.gov/mission_pages/NPP/main/index.html)) satellite in an Earth inclined low Earth polar orbit crossing the equator at about 13:30 local solar time. The OMPS suite of instruments consists of three spectrometers, a spatial nadir mapper OMPS-NM, a nadir looking ozone profiler, and a limb viewing profiler. The OMPS-NM side-to-side looking nadir mapper spectrometer (side-swath of 2000 km) has a spectral range of 300 to 380 nm with a spectral resolution of 1.1 nm and a nadir spatial resolution of 50 x 50 km2 (Jaross et al., 2012; McPeters et al., 2019). OMPS-NM occasionally observes at large backscattering angles in the equatorial region but never at higher latitudes. This paper uses the 380±0.55 nm LER data from the downward looking spatial mapper OMPS-NM to compare with the observations from EPIC.

Unlike the visible and near-IR channels of EPIC, the 380 nm and 388 nm UV reflectivities of clear-sky snow/ice-free scenes are very low over both land and oceans for both EPIC and OMPS-NM. The average clear-sky LER (Bhartia et al., 1993, Krotkov et al., 1998, 2001; Herman et al., 2001, Herman et al., 2018a) of the snow/ice free Earth’s surface is about 0.05 (Herman and Celarier, 1997) after the calculated Rayleigh scattering amount from the surface to the top of the atmosphere (TOA) has been subtracted. The observed UV LER is almost independent of seasonal surface vegetation effects and shadowing effects from the terrain and vegetation and there is almost no atmospheric absorption.

The main interest is the relative year-to-year change in reflected solar energy RSE from 388±1.5 nm or 380 ± 0.55 nm solar irradiance reflected from the illuminated portion of the Earth as seen by EPIC and OMPS-NM during the period June 2015 to June 2021. This includes the period (2020-2021) when the minimum EPIC Sun-Earth Viewing angles SEV were near 2O (SEV = 180O - BA), compared to previous years 2015-2019 when the minimum SEV angles were larger (4O- 6O). The goal is to see which latitude bands contribute to the apparent increased back reflection observed by EPIC in June and December 2020 and 2021, and to compare relative changes in percent reflected energy with SEV angles and the corresponding measurements from OMPS-NM.

The paper will show that there was an increase in Southern Hemisphere SH RSE at mid-latitudes when the SEV angle is approximately 2O in December 2021, but that the equivalent observation at small SEV angles in the Northern Hemisphere NH during June 2021 does not show an increase relative to previous years. This suggests that part of the effect seen in visible wavelengths (Marshak et al., 2021) was from increase in cloud reflectivity and not just scattering angle effects.

**2.0 Reflected Solar Energy RSE and Percent Difference PSE**

The 1 AU solar flux at l = 388 nm is approximately 1.04 W m-2nm-1 (Thuillier et al., 2003) and at l = 380 nm is 1.3 W m-2nm-1. The EPIC filter has an almost rectangular Full Width Half Maximum band pass of Dl = 3 nm (Herman et al., 2018a) yielding a solar irradiance at 1 AU at the top of the atmosphere of ETOA = 3.12 Wm-2. For OMPS-NM at 380±0.55 nm, ETOA is 1.43 Wm-2. All of the following results will be expressed as a percent reflected energy PSE(t,q) incident on the area of a flat disk of radius RE and area pRE2, where PSE(t,q) is weighted by the area of each latitude band and the cosine of the solar zenith angle SZA appropriate for the latitude q, longitude f, and time t from start of the EPIC radiance data on 17 June 2015 18:44:39 GMT.

The intensity of the solar irradiance FSUN(t) on the Earth’s surface at a given Greenwich Mean Time (GMT) is reduced in proportion to the cosine of the solar zenith angle SZA = z(q,f,d), where d = the Earth’s declination angle -23.45O ≤ d ≤ 23.45O (Eqs. 1-9). Further variation is given by the changing Sun-Earth distance caused by the approximately elliptic orbit of the Earth about the Sun. The illuminated Earth of mean radius RE= 6371 km is divided into latitude by longitude grids of 0.25O x 0.25O. The reflected energy Ei(qi,t) contribution of each latitude band qi is approximately proportional to the illuminated latitude-band area Ai on the Earth (Eqs. 1-5) from M illuminated grid points. For convenience, the small (2Dq = 0.25O) latitude band contributions can be summed into 18 Da = 10O latitude bands -90O < a < 90O using Eq. 6 with the energy reflected in each band in Watts (Eq. 8), or in percent of RSE appropriate for a given latitude band (PSE(t, ak) in Eq. 9).

For OMPS-NM, the spatial grid is Dq = 0.5O and Df = 0.5O corresponding to its coarser spatial resolution and the summation in Eq. 5 is over 360O since OMPS-NM makes 1 measurement per 24 hours for a given grid point at fixed solar time near 13:30 local solar time. N = 40 for EPIC in Eq. 7 and 20 for OMPS-NM.

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|  | (1)  (2)  (3)  (4)    (5)    (6)    (7)  (8)  (9) |

The EPIC PSE(t,ak) are corrected for the change in the area of the illuminated Earth seen by EPIC from decreases in orbit SEV angles during 2021-2022 compared to the average area of previous years using the ratio RA (Eq. 10).

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| RA = Area in 2020/<Area 2015-2019>, where <…> denotes average | (10) |

From Eqs. 1-9, the EPIC sunrise to sunset 388±1.5 nm reflected energy (90OS to 90ON) from clouds, aerosols, the surface, and snow/ice is PSE = 29.2% of the incident solar energy including the surface contribution. The global average RSE (90OS to 90ON) has a maximum in December and a minimum in June showing that the SH cloud reflected energy is greater than that in the NH. Annual global integrals from 2016 to 2020 of reflected energy are almost constant.

The global percent reflected energy PSE appears to slightly increase during December 2020 (SEV = 1.95O) (Table 1) compared to the average from previous years (2015-2019) when the SEV angles are larger (Fig.1). The effect during the summer is larger at southern latitudes and decreased during summer (June) at northern latitudes. Sections 2.1 (SH) and 2.2 (NH) will show which latitude bands contribute to the change in reflected energy during 2020 – 2021 when the SEV angles are smallest.

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| Fig.1 Panel A: Percent reflected solar energy PSE for the Earth from 90OS to 90ON in the narrow band 388±1.5 nm (black circles one for each EPIC scene) from clouds, aerosols, and surface as a function of time and SEV angle (orange curve – right axis). There are about 6000 points per year. Panel B: 2-week running average to show the December and June peaks more clearly. The missing data points from June 2019 to February 2020 are from a satellite pointing system failure that was repaired in February 2020. | |

The global percent of incident reflected energy mostly from clouds PSE = 29.2% varies from 24% to 38% depending on the month of the year. The global cloud reflected energy is dominated by the SH summer (December-January).

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| Table 1 Minimum SEV angles | |
| Date | SEV (Deg) |
| 19 March 2020 | 3.25 |
| 16 June 2020 | 2.46 |
| 15 September 2020 | 2.10 |
| **11 December 2020** | **1.95** |
| 7 March 2021 | 2.05 |
| **3 June 2021** | **1.83** |
| 2 September 2021 | 1.88 |
| 29 November 2021 | 2.53 |
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Most of the apparent scatter of data points for EPIC in Fig. 1 is not measurement noise but instead is the result of obtaining multiple measurements of the rotating Earth every day. Figure 2 contains a small subset of data points obtained from 20 March 2016 to 30 March 2016 showing the successive maxima occurring from clouds over the Pacific Ocean and the minima over Africa. The minima are caused by the almost cloud-free atmosphere over most of the land area of Africa, which has low 388 nm LER (Herman et al. 2018b). Most of Africa has little cloud cover per km2 compared to other regions (e.g., <https://epic.gsfc.nasa.gov/?date=2022-06-09>) and the land surfaces are dark (LER < 0.05) at 388 nm (Herman et al., 2018b).

This is opposite of the behavior for the visible and NIR channels that have much higher surface reflectivity, especially over Africa and over vegetation. Since the data are from March, the NH winter cadence applies for 13 points per 24 hours compared to the NH summer cadence of 21 points per 24 hours. The same interpretation of apparent scatter in EPIC data points applies to every figure.

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| Fig. 2 EPIC’s daily variation of PSE(t) caused by the Earth’s rotation for Dq = 90OS to 90ON from 20 March 2016 to 30 March 2016 corresponding to the grey circles in Figure 1A. The numbers 20 to 30 represent the dates in March 2016. Maxima are over the Pacific Ocean and minima over Africa. |

**2.1 Southern Hemisphere**

The maximum percent reflected energy PSE in each hemisphere occurs during their respective summer months corresponding to the minimum SZA at a given latitude caused by the varying solar declination angle ±23.45O during the earth’s annual orbit about the sun. After RA correction (Eq. 10) for the increased observable area compared to 2016-2019 (Fig. 3), there is still a PSE increase (Fig.4) in the SH during December 2020 (SEV=1.95O) for latitudes greater than 30O compared to previous years. A smaller increase in PSE occurs at the end of November 2021 (SEV = 2.53O). In the NH there are also correspondences of the summer PSE maxima with minimum SEV angle (1.83O) in June 2021 and June 2020 (2.46O). As shown later, NH PSE values at small SEV angles do not show an increase compared to previous years.

Because of the small SEV angle, EPIC observes more of the illuminated disk at SEV=2O than at SEV=6O. The missing area near the Earth’s limb rotates east and west and north and south with the satellite orbit relative to the Earth-Sun line. The worst case for mid-latitudes is when the plane of the orbit is aligned with the latitude of interest. Figure 3 shows ratio of observed cosine weighted illuminated areas as a function of month of the year for four SH latitude bands as observed by EPIC during 2020-2021 with SEV ≈ 2O to that during the years 2015-2019 when SEV was 4O- 6O. The ratios of the observed areas in December, RA(SH) are 1.03 for 35OS, 55OS, and 65OS, and 1.04 for 45OS. To compare the reflected energy from 2015-2019 to that from 2020 Eqs. 8 and 9 for 2020 must be divided by RA(SH). For this purpose, the smoothed Loess(2-months) data are used (Cleveland, 1981). The SH results are shown in Fig.3 for four latitude bands.

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| Fig. 3 The SH area correction ratio RA(SH) from (Eq. 10) of the Earth’s area within the specified latitude bands seen by EPIC in 2020 to that seen during the years 2015-2019. In December 2020, the ratio is 1.03 for 35OS, 55OS, and 65OS, and 1.04 for 45OS. The red curve is Loess(2-months). The inset for 70OS-60OS shows the details near December 2020. |

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| Fig. 4 Area corrected weekly average EPIC SH percent reflected solar energy PSE7(388±1.5 nm) band (grey circles), the SEV angles (orange). Magnified details are shown in the Appendix Fig. A1. |

The approximate equivalent of a seven-day least-squares running average (Cleveland, 1981), Loess(f), where f= fraction of data points in the entire time series, is performed on the PSE data set corresponding to approximately 13 illuminated Earth views per 24 hours in December using Loess(0.035). For the 7 days surrounding the minimum SEV=1.96O on 10 December, the range of SEV angles that are included in the averaged PSE spans 1.96O to 2.43O. The specific day of the December peak PSE varies with latitude so that it occurs slightly after the 10 December minimum SEV at latitudes 90OS to 70OS but closely matches the minimum SEV time for latitudes 70OS to 10OS (Fig. 4) with lower latitudes 40OS to 10OS having a wider PSE(ak,t) peak.

The SH quantity of interest is the peak during December 2020 when the SEV angle was about 1.95O compared to the average peak of the preceding years when the SEV angle was 6O to 7O (Figs. 1 and 4). Figure 4 shows SH EPIC percent reflected energy PSE(388±1.5 nm) for six 10O wide latitude bands compared to the SEV angles with the RA correction applied. The dates of the minimum SEV angles are shown in Table 1 with a clear minimum SEV angle match on 11 December 2020 and 29 November 2021 (Fig. 4 and its magnified version in Appendix Fig. A1), except at latitudes poleward from 70OS where the peak PSE occurs just after the SEV minimum. At mid-latitudes, 30OS to 70OS the SEV December minimum and the PSE maximum match closely. For lower latitudes 0 – 20, the PSE peaks do not show an increase and are significantly wider.

An alternate graph comparing different years is shown in monthly average <PSE30> (Fig. 5) for the SH showing that the largest effect is in the 40OS to 50OS latitude band centered in December 2020 (orange curve).

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| Fig. 5 Monthly average PSE30 of SH annual time series of percent reflected energy at 388±1.5 nm for 5 years, 2015 – 2021 for 4 latitude bands. The monthly average <PSE30> for 60OS - 70OS uses adjacent averaging instead of Loess to avoid an artifact from Loess in June (slight negative values). | |

Seven-day average <PSE7> peak values from Figs. 4 are summarized in Fig. 6 as a function of latitude. Figure 6 shows comparisons of <PSE7> peaks in December 2020 and November 2021 with previous years, 2015 - 2019. The maximum <PSE7> is at 45OS during December 2020 (4.03%, orange curve) compared to the 4-year average (3.73%). Similar data from November 2021 shows almost no difference (3.74%) compared to the 4-year average (3.77%).

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| Fig. 6 Seven-day least squares running averages Loess(0.035) of <PSE7> values from Fig. 3 as a function of latitude for the periods Dec 2020 (SEV = 1.95O) and November 2021 (SEV = 2.53O) compared to the average of the preceding 4 years, 2015-2019 (4O < SEV < 6O). The bracket symbols <A-B> denote average. The inset shows the percent difference PD as defined in Eq. 11. Standard deviation bars are estimated assuming the combined standard deviations are independent. |

The EPIC SH cloud peak reflected energy aligns with the small SEV angle (1.96O) in December 2020 and the percent difference PD (Eq. 11) is PD = 7% compared to the preceding 4 years. The OMPS-NM December 2020 peak (Fig. 7) also exceeds the average of the preceding 5 years by PD = 5%. This suggests that the increase in December 2020 is from increased cloud cover and not from enhanced backscatter when SEV = 1.96O.

The percent difference PD is defined in reference to the 2015 or 2016 to 2019 averages (Eq. 11)

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Figure 7 shows the hemispheric zonal average for OMPS-NM for the latitude band 50OS-40OS compared to 1 to 2 hour time-dependent PSE from EPIC . The values of OMPS-NM reflected energy have less point-to-point variation than those for EPIC, since the OMPS-NM are for mid-day are the hemispheric zonal average reflected radiances while EPIC observes spatially resolved reflected radiances from near sunrise to near sunset. The quantities of interest are the relative values for each observing instrument during each summer maxima for June and December 2020 and 2021 as a function of latitude compared to the maxima in previous years, 2015-2019.

The peak values for the December solstice maxima are in close agreement while the June solstice minima do not agree PSE(EPIC, June) < PSE(OMPS-NM, June) since PSE(OMPS-NM, June) are computed from a zonal average that always includes more clouds than the minimum values of PSE(EPIC, June) occurring over Africa (Fig. 2).

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| Fig. 7. A time series of OMPS-NM hemispheric zonal average PSE (1 point per day grey circles) 2015-2021.5 and a 1-week average (red curve) for the band 40OS to 50OS compared to EPIC PSE. The red-curve is a 1-week running average Loess(0.028). | |

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| Table 2 Summer Solstice Area Ratios (Figs 3 and 8)  RA= A(2020)/<A(2015-2018)> | | | |
| Latitude | RA | Latitude | RA |
| 65OS | 1.03 | 65ON | 0.97 |
| 55OS | 1.03 | 55ON | 0.97 |
| 45OS | 1.04 | 45ON | 0.99 |
| 35OS | 1.03 | 35ON | 0.99 |
| 25OS | 1.04 | 25ON | 1.00 |
| 15OS | 1.02 | 15ON | 0.95 |
| 5OS | 1.02 | 5ON | 1.01 |

**2.2 Northern Hemisphere**

The area corrected (Fig. 9) NH June peaks in PSE7 (Fig. 8) coincide with the SEV minima of 16 June 2020 (2.46O) and 3 June 2021 (1.83O) in 5 of the 6 latitude bands shown in Fig. 8. Exceptions are for 0 to10ON, 10ON to 20ON, and 20ON to 30ON. For the latitude bands where there is coincidence between the maxima in PSE7(t,q,10) and minima SEV one might expect enhanced backscattering corresponding to the June minimum SEV compared to previous years as there is in the SH. However, this is not the case (Figs. 8 and 10).

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| Fig. 8 Area corrected weekly average EPIC NH percent reflected solar energy PSE7(388±1.5 nm) band (grey circles), the SEV angles (orange). Magnified details are shown in Appendix Fig. A1. |

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| Fig. 9 The area correction ratio RA(NH) from Eq. 10 of the Earth’s area within the specified latitude bands seen by EPIC in 2020 to that seen during the years 2015-2019. In June 2020, the ratio is 0.96 for 35ON, 0.96 for 45ON 0.97 for 55ON, 0.93 for 65ON. The red curve is Loess(2-months). |

Because the DSCOVR orbit about L1 has an approximately six-month period superimposed on a longer period of about 5 years when the orbit shape changes from an ellipse to a circle and back to an ellipse, the observed area effect in the NH was different than in the SH when the SEV angles became small. The June solstice area ratio values are less than 1.

A 7-day average analysis <PSE7> is shown in Fig. 8 for the NH June maxima with 23 views per 24 hours and a Loess(0.006) that is similar to that for the SH (Fig. 6). <PSE7> peak values from Figs. 8 are summarized in Fig. 10 as a function of latitude showing comparisons of <PSE7> peaks in June 2020 and June 2021 with previous years, 2015 - 2019.

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| Fig. 10 Peak 1-week least squares running averages Loess(0.006) of <PSE7> values from Fig. 8 as a function of latitude for the periods June 2020 (SEV = 2.46O) and June 2021 (SEV = 1.83O) compared to the average of the preceding 4 years, 2015-2019 (4O < SEV < 6O). The symbols <A-B> denote average. Inset is Percent Difference PD vs Latitude as in Eq. 11. Standard deviation bars are estimated assuming the combined standard deviations are independent. |

The June 2021 peak <PSE7> data (SEV = 1.83O) shows a decrease (PD = -3.6%) at (40ON – 50ON) relative to the preceding 4 years (2015-2019) suggesting that there was no significant backscatter effect and that the cloud amount decreased. The period June 2020 (SEV = 2.46O) shows no significant change at 45ON and an increase at 55ON of PD = 9.5%, which is probably due to increased cloud amount since the SEV angle is 2.46O. The NH time monthly average time series for each year (Fig. 11) can be compared in a manner similar to Fig. 4 showing that the small SEV period during 2021 (blue curve) does not show an enhanced backscatter effect, but instead a decrease in reflected energy compared to <2015-2019>.

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| Fig. 11 Monthly average PSE30 of NH annual time series of percent reflected energy at 388±1.5 nm for 4 years, 2015 – 2021. The period 2018-2019 is not shown since the data are missing starting on 28 June 2019 to February 2020. | |

**3.0 Summary**

EPIC observed 388±1.5 nm backscattered irradiances are mostly from clouds since the average 388 nm reflectivity of the Earth’s snow/ice-free surface is small, approximately 0.05. At all non-equatorial latitudes, the maximum reflected energy occurs near the summer solstice time (minimum SZA). During the period 2020 to 2021, the backscatter angle became close to 178O in December 2020 compared to 174O – 176O in prior years (2015 – 2019). Two recent papers, Marshak et al., (2021) and Penttilä et al. (2021) suggested that the increase in observed reflected sunlight might be from enhanced backscattering in the SH when the SEV angle was close to 2O. The increase seen by Marshak et al. (2021) was mostly from land surfaces in the visible wavelength ranges. The analysis of Penttilä et al. (2021) suggested that about half might be caused by increased cloud cover.

The 388 nm LER showed that there was a significant increase in reflected energy, PD = 7%, in the latitude band 40OS - 50OS during December 2020 with smaller effects at other SH latitudes PD = 2.9% at 35OS and 5.3% at 55OS and none near the equator. If the increases were due to enhanced backscatter, one would have expected the same enhanced backscatter in the NH during June 2021 from PSE peaks that coincide with the SEV minimum (SEV = 1.83O). Instead, there was a decrease at 45ON and almost no increase at 55ON. The PD = 9.5% increase at 55ON (SEV = 2.46O) shown in Fig. 11 suggests that the increase was from change in cloud cover in the NH with backscatter effects being small. A comparison at 40OS – 50OS with the polar orbiting OMPS-NM (SEV greater than 40O – 23.45O = 16.55O) percent reflected energy at 380±0.55 nm showed a 5% increase in December 2020 at 45O±5OS implying there was an increase in cloud cover seen by both EPIC and OMPS-NM. The global annual integral of reflected 388±1.5 nm energy from clouds is almost constant for the period 2015 to 2020 at 29.2% of the incident solar irradiance.

**4.0 Appendix**

Figure A1 shows magnified details for 2 latitude bands each in the NH and SH along with the coinciding minimum SEV data.

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| Chart, bar chart, histogram  Description automatically generated | Chart, bar chart, histogram  Description automatically generated |
| Chart, bar chart  Description automatically generated | Chart, bar chart, histogram  Description automatically generated |
| Fig. A1 Magnified samples from Figs. 3 and 7 showing SEV minimum coincidences with PSE maxima in the SH and NH. The SEV are colored orange. | |