2020 DSCOVR Science Team Meeting

EPIC vs GCM: Longitudinal Variability of Planetary Albedo and Cloud Radiative Properties

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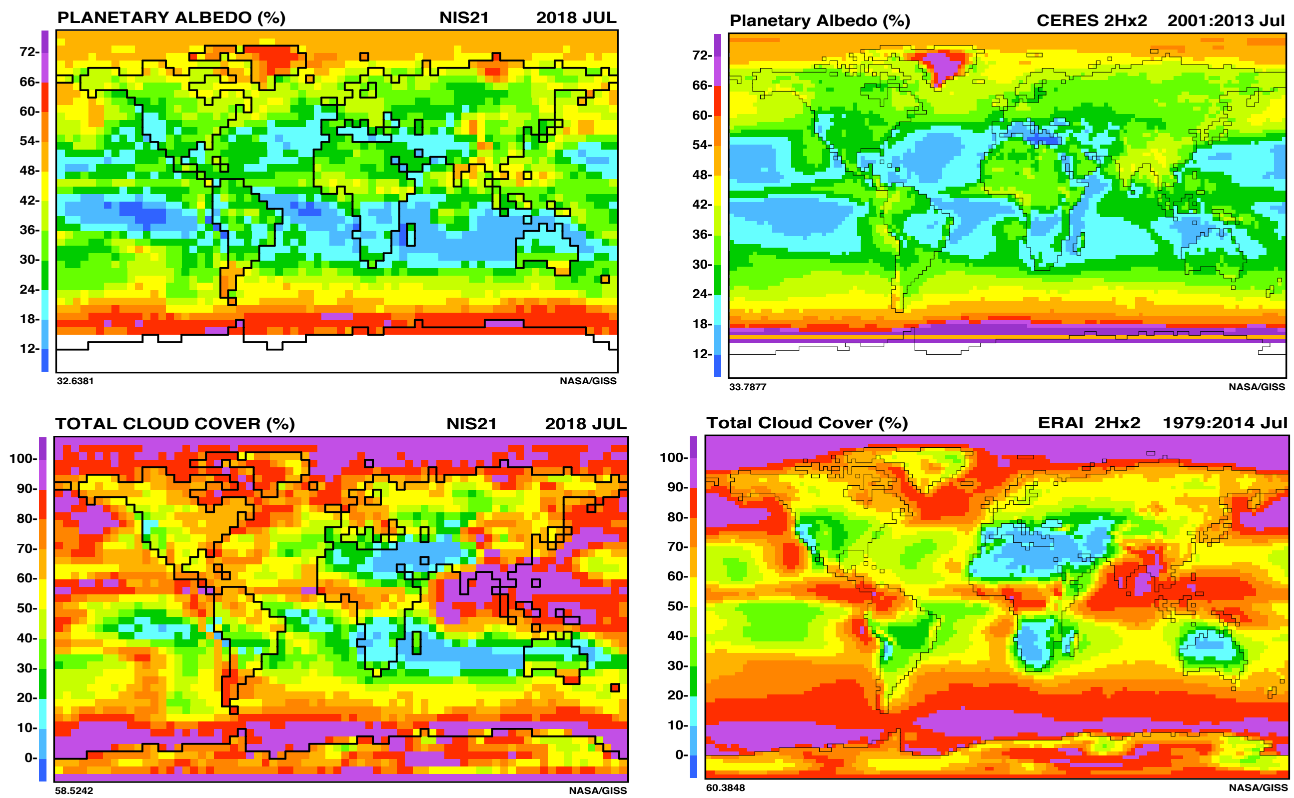
Conclusions

1. NASA's DSCOVR Mission ***EPIC and NISTAR data provide a new and unique diagnostic perspective*** for assessing global climate model performance.
2. EPIC narrow-band, high spatial resolution images of the Earth's sunlit hemisphere provide continuous monitoring of climate system processes.
3. NISTAR near-backscatter SW, NIR broad-band and SW+LW total-spectrum radiances of the unresolved Earth seek to address global energy balance.
4. ***NISTAR data are unique for their NIR/SW spectral ratio diagnostic capability*** for assessing global climate model radiative transfer spectral treatment.
5. DSCOVR measurements have ***direct relevance to exoplanet investigations***.
6. NISTAR spectral ratio time series can deduce exoplanet rotation period, and cloud and vegetation/surface-type distribution and their seasonal variability.
7. EPIC imagery serves to validate inferences from NISTAR spectral ratio data.

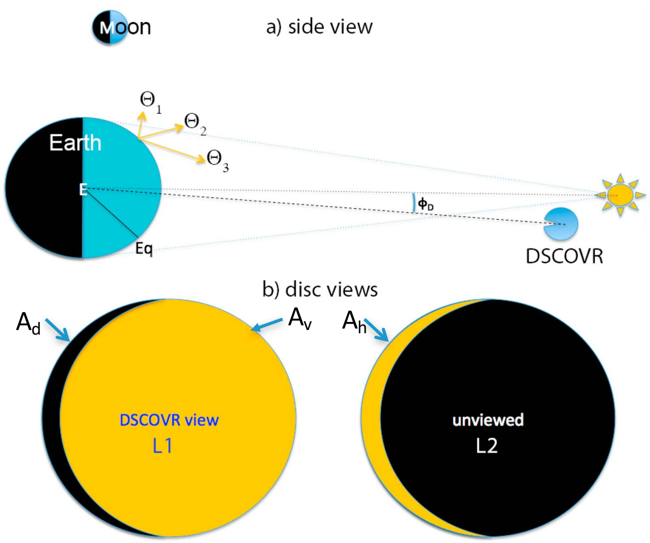
Current Common Format Model/Data Comparisons



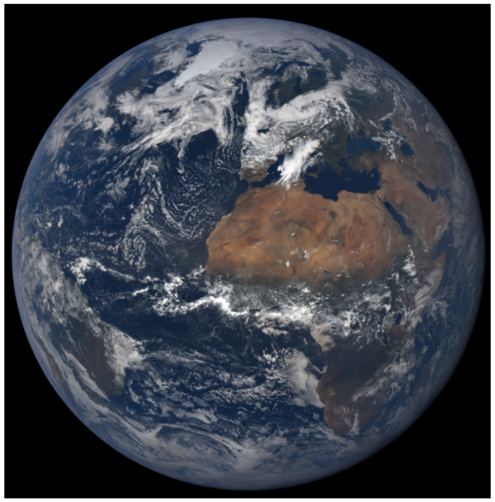
Qualitative model/data comparisons: GCM Planetary Albedo & Cloud Cover *vs* CERES Planetary Albedo & ERAI Cloud Cover.

Qualitative because: (1) both the GCM and the real World exhibit quasi-chaotic behavior, and (2) the space-time sampling of GCM output data and that of Earth observational data is different, and thus subject to bias and aliasing.

EPIC / NISTAR Perspective on SW Flux Determination



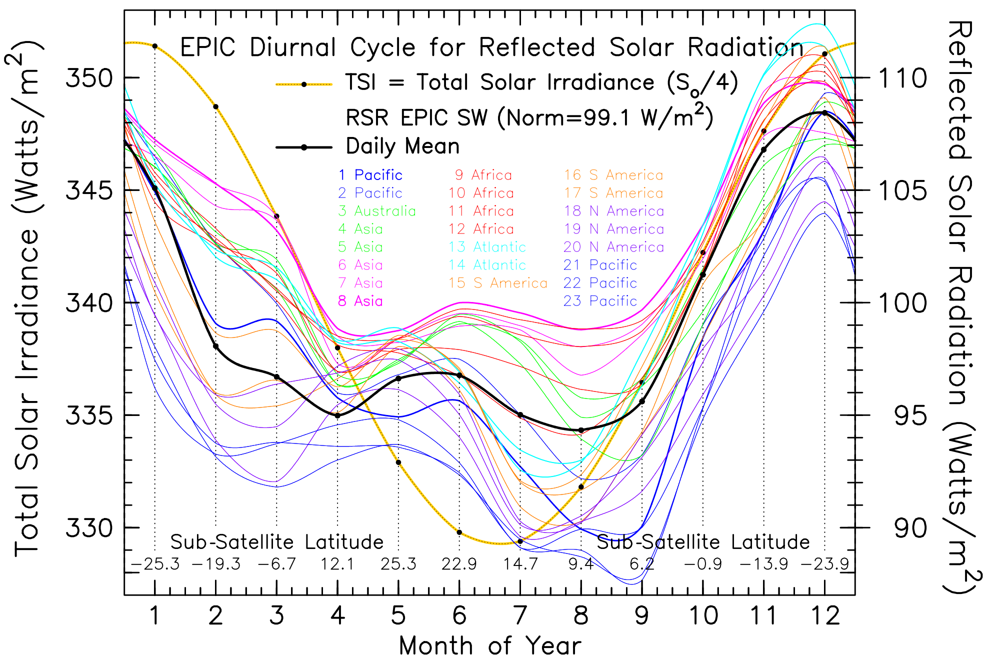
Epic 1/26/17



Epic 6/30/17

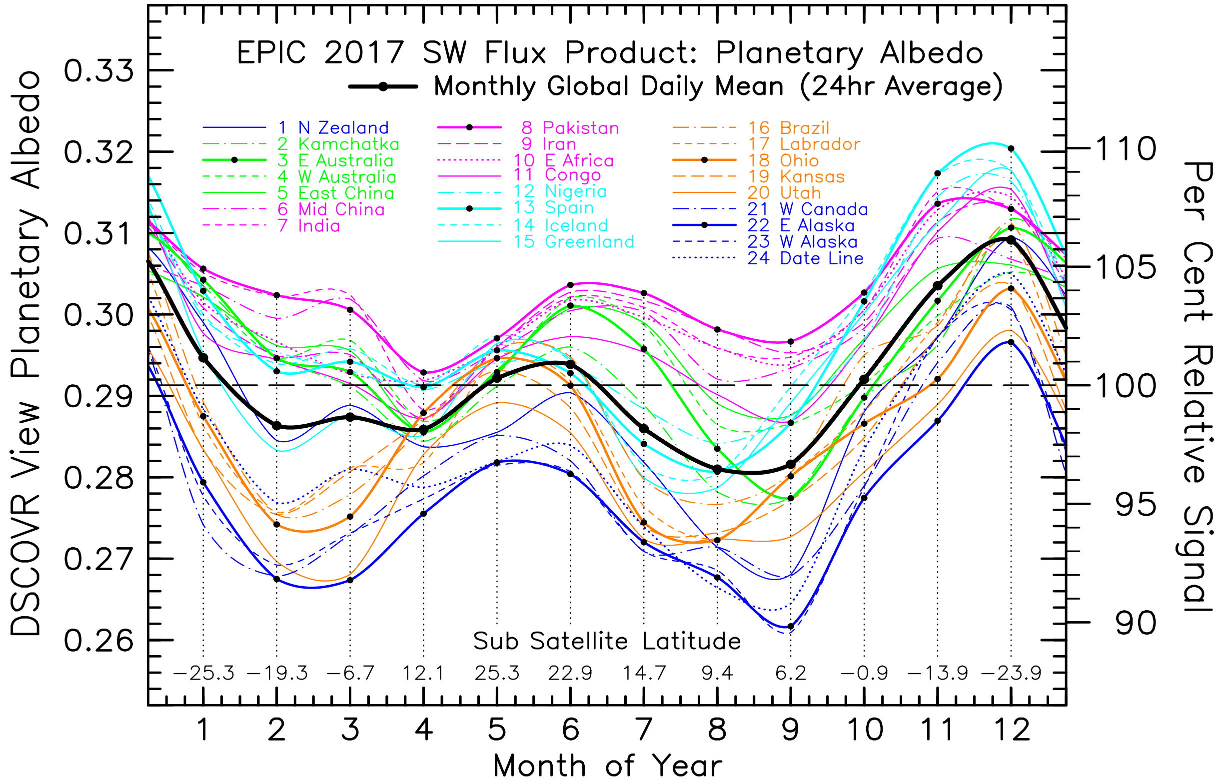
EPIC and NISTAR viewing geometry from the Lissajous orbit around the Lagrangian L1 point in the direction of the Sun. Left panel (Fig. 1 of Su et al., 2018) depicts the EPIC/NISTAR viewing aspects. Right panels depict sample near-hourly images of Earth (https://www.epic.gsfc.nasa.gov) from which detailed sunlit hemisphere climate data can be derived. Note that in orbiting the Lagrangian L1 point, EPIC and NISTAR view 92-97% of the sunlit hemisphere, never 100%.

EPIC SW Flux Data with (hourly) Longitudinal Sampling



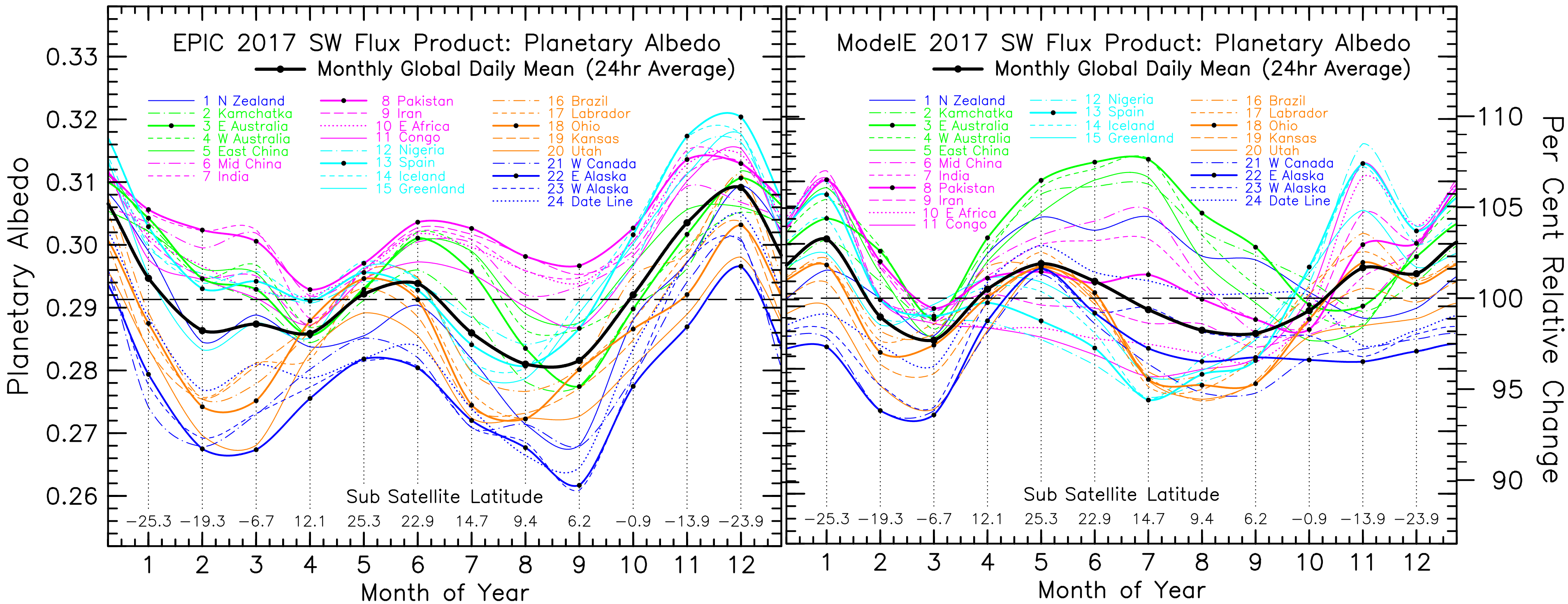
Monthly-mean SW fluxes were derived from EPIC data (Su et al, 2018), using a CERES-based radiance-to-flux conversion. The "seasonal spaghetti" map depicts SW fluxes (right-hand Y-scale) normalized to global annual mean 99.1 W/m^2 (Loeb et al, (2018), which are referenced by their UT noon-time Sun and corresponding color-coded longitude (including the local geographic landmark). The solid black line is the daily longitudinal mean (for EPIC 2017 data). The heavy yellow line (left-hand Y-scale) is the seasonal global-mean Total Solar Irradiance (TSI).

Longitudinally Sampled Planetary Albedo from EPIC SW Flux Product



EPIC derived SW fluxes (Su et al, 2018) are normalized to global annual mean 99.1 W/m^2 (Loeb et al, (2018). Monthly-mean SW fluxes, divided by the seasonal global-mean Total Solar Irradiance (TSI) yield the planetary albedo. The planetary albedos are centered on their color-coded longitude and and are tagged by UT noon-time and a landmark. Heavy black line depicts the longitudinally averaged planetary albedo of Earth derived from EPIC data using CERES-based radiance-to-flux conversion.

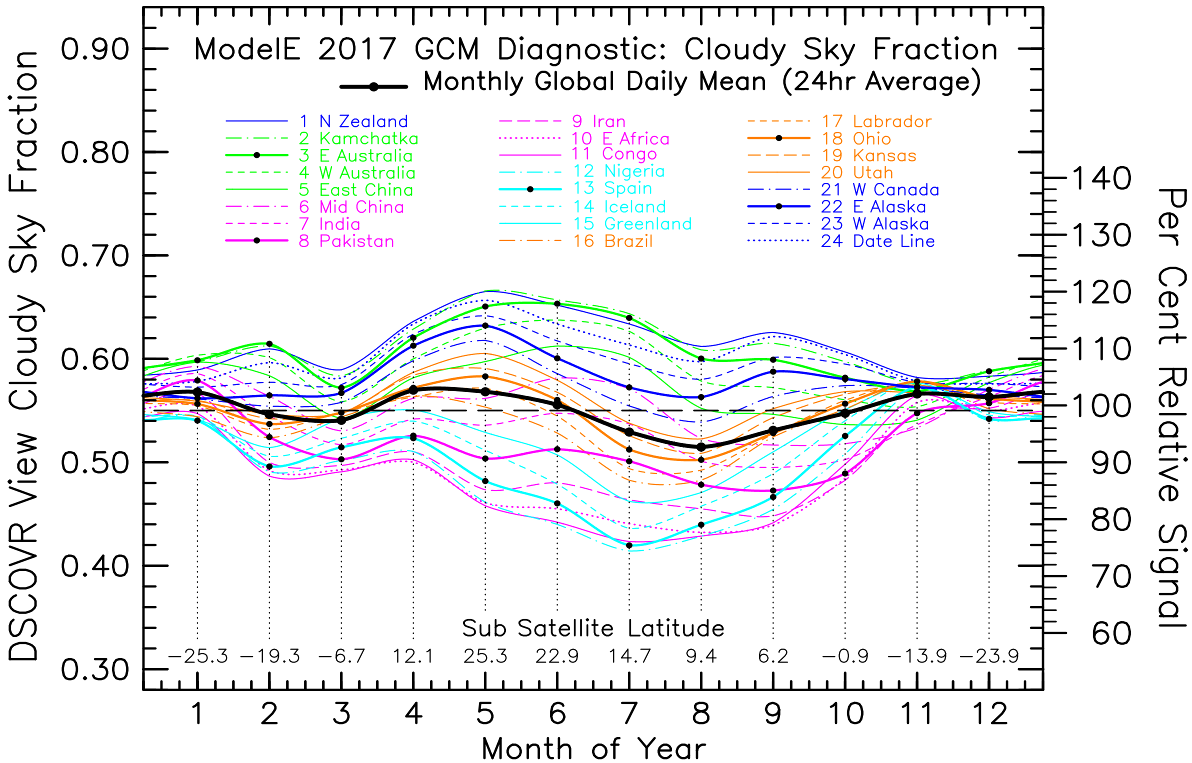
EPIC *vs* GCM: Planetary Albedo from SW Flux Data



DSCOVR-view model/data planetary albedo comparison points to: (1) need for a stronger cloud response over land areas relative to the oceans, and (2) inadequate summer hemisphere cloud response, especially during December, suggesting that the GCM (ModelE_2.1) relative humidity threshold "cloud tuning" parameter needs to be more physically based.

***This is an example of Quantitative climate-type model/data comparison utilizing self-consistent space-time sampling*.**

EPIC-View ModelE_2.1 Cloud Cover Fraction (percent)



Seasonal spaghetti map of dayside hemisphere monthly-mean cloud cover, color-coded for every 15 degrees of longitude, and tagged with the UT hr (for local noon-time Sun) and corresponding geographical location. Note that maximum May-June-July cloud cover occurs over West Pacific (E Australia-green), next is East Pacific (E Alaska- dark blue). Lowest is over the Atlantic (Spain- blue-green), next higher is Asia (Pakistan-magenta). Global-mean seasonal cloud fraction is black, and similar to North America (Ohio-orange). Note the small diurnal range for Nov-Dec-Jan.

EPIC-Derived: 2018 All-cloud (EPIC images available per day/month)

DayMon	Jan=1	Feb=2	Mar=3	Apr=4	May=5	Jun=6	Jul=7	Aug=8	Sep=9	Oct=10	Nov=11	Dec=12	Annual
1	12	13	13	13	22	13	22	0	22	13	13	13	169
2	10	6	0	10	21	22	22	21	22	13	13	13	173
3	13	15	13	10	22	22	22	22	13	11	13	13	189
4	12	11	13	3	22	22	22	22	9	12	13	13	174
5	11	9	13	10	22	19	22	22	12	5	13	13	171
6	13	13	13	10	22	21	19	22	13	12	13	13	184
7	13	13	12	10	22	22	22	22	13	13	13	11	186
8	13	13	10	10	22	18	22	20	13	11	13	13	178
9	13	12	10	10	22	0	22	22	13	9	11	13	157
10	13	13	13	11	22	0	22	22	13	13	13	12	167
11	13	13	13	13	21	6	22	22	12	13	13	13	174
12	13	13	9	13	22	22	22	22	13	11	13	13	186
13	13	13	13	13	22	22	22	22	13	12	13	12	190
14	12	13	13	13	21	22	22	22	11	13	10	13	185
15	0	13	13	13	22	22	21	8	13	4	13	13	155
16	13	13	13	9	22	22	22	0	13	12	13	13	165
17	13	13	13	12	22	22	22	19	13	12	12	8	181
18	13	13	13	13	22	22	22	11	10	4	13	13	169
19	13	13	13	12	21	22	20	17	13	12	13	13	182
20	12	13	13	11	21	22	18	22	13	3	12	13	173
21	13	13	12	13	11	22	21	22	13	2	13	13	168
22	13	13	0	13	16	19	22	22	13	13	13	13	170
23	12	13	13	13	22	22	20	22	13	4	13	13	180
24	13	13	13	12	22	22	22	22	6	0	12	13	170
25	13	13	12	22	18	14	22	22	13	0	13	11	173
26	13	13	13	22	22	21	22	22	11	13	13	13	198
27	13	12	12	19	22	22	0	22	13	13	10	13	171
28	13	13	13	22	22	22	22	17	13	13	12	13	195
29	13	0	13	22	22	21	22	16	13	13	9	13	177
30	13	0	11	0	21	20	15	21	13	13	13	13	153
31	0	0	13	0	6	0	21	22	0	13	0	13	88
Sum Mnthly	367	351	361	377	639	568	639	590	388	305	374	392	5351

EPIC-Derived: 2018 All-cloud (EPIC data points per UT longitude/month)

EPIC-2018 Longitudinal and Seasonal Variability: All-Cloud Number UThr Interpolated Points /Month

hourUT	Jan=1	Feb=2	Mar=3	Apr=4	May=5	Jun=6	Jul=7	Aug=8	Sep=9	Oct=10	Nov=11	Dec=12	Annual
0	25	24	24	24	29	25	29	28	26	20	24	27	305
1	29	27	28	28	29	27	30	28	30	23	29	31	339
2	29	27	28	28	29	27	30	29	30	24	30	31	342
3	29	27	28	28	29	27	30	29	30	25	30	31	343
4	29	27	29	28	30	27	30	29	30	24	30	31	344
5	29	27	29	28	30	27	30	29	30	25	30	31	345
6	29	27	29	28	30	27	30	29	30	26	30	31	346
7	29	27	29	28	30	27	30	29	30	23	30	31	343
8	29	27	29	28	30	27	30	29	30	25	30	31	345
9	29	27	29	28	30	27	30	29	30	24	30	31	344
10	29	27	29	28	30	27	30	28	30	23	30	31	342
11	29	27	29	28	30	27	30	28	30	24	30	31	343
12	29	27	29	28	30	27	30	28	30	24	30	31	343
13	29	27	29	28	31	28	30	27	30	23	30	31	343
14	29	28	29	28	31	28	30	27	30	24	30	30	344
15	29	28	29	29	31	28	30	27	30	23	30	30	344
16	29	27	28	27	31	27	30	27	29	22	30	30	337
17	29	27	28	27	30	27	29	27	29	23	30	30	336
18	28	27	28	23	30	27	29	27	28	23	29	30	329
19	28	27	27	20	30	27	29	27	28	22	29	30	324
20	28	27	27	20	30	26	29	27	28	23	29	30	324
21	28	26	27	19	30	26	29	26	28	23	28	30	320
22	27	26	25	19	29	25	28	26	28	22	28	30	313
23	19	19	17	16	29	25	27	26	22	16	21	22	259
Global	676	637	663	616	718	643	709	666	696	554	697	722	7997

EPIC-Derived: 2018 All-cloud Sky Fraction (percent)

EPIC-2018 Longitudinal and Seasonal Variability: All-Cloud EPIC Sky-view Cloud Fraction (PerCent)

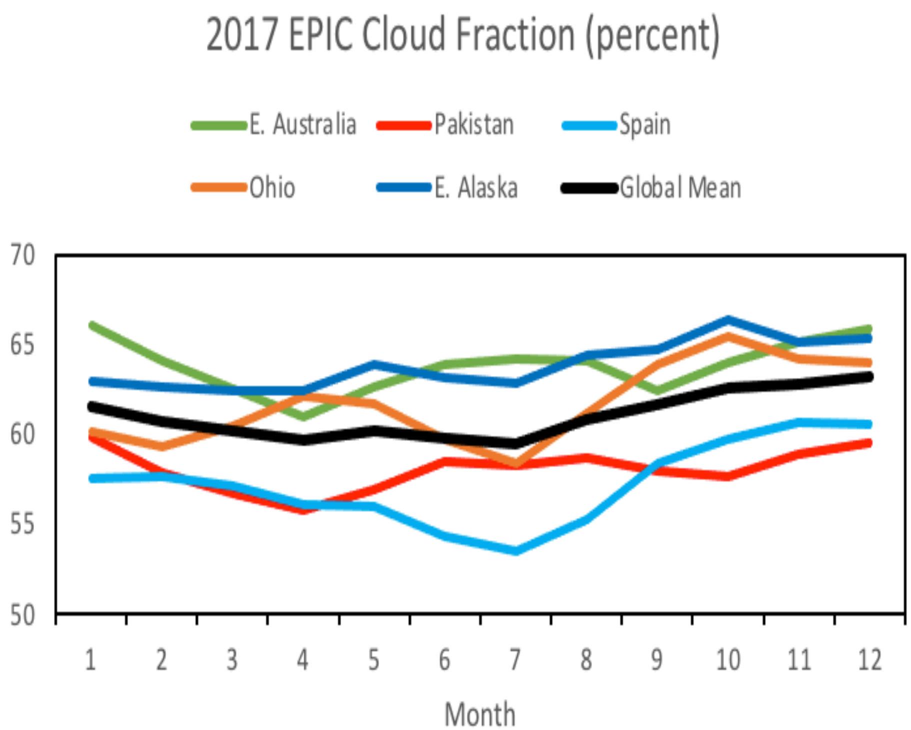
hourUT	Jan=1	Feb=2	Mar=3	Apr=4	May=5	Jun=6	Jul=7	Aug=8	Sep=9	Oct=10	Nov=11	Dec=12	Annual
0	68.10	68.40	66.10	62.06	62.96	64.51	65.35	65.36	63.80	63.16	66.06	68.30	65.33
1	68.00	67.69	65.80	62.13	62.89	64.51	65.45	65.33	63.44	62.49	65.85	68.20	65.14
2	67.82	66.60	65.03	62.10	62.91	64.59	65.79	64.86	62.53	61.94	65.57	67.78	64.79
3	67.15	65.67	63.96	61.66	62.78	64.50	65.76	63.49	61.37	61.50	64.52	66.79	64.09
4	66.13	64.87	63.03	60.83	61.98	63.73	64.79	62.02	60.28	60.80	62.95	65.38	63.06
5	64.90	63.92	61.87	59.74	60.84	62.26	63.18	60.96	59.67	59.76	61.69	64.10	61.90
6	63.32	62.56	60.37	58.69	59.67	60.59	61.51	60.28	59.13	58.75	60.61	62.86	60.69
7	60.85	60.63	58.86	57.83	59.00	59.89	60.63	59.86	58.82	58.57	59.78	61.19	59.66
8	58.76	59.42	58.01	57.44	58.66	59.60	60.05	59.58	58.81	58.84	59.36	59.72	59.02
9	58.10	59.65	58.45	57.97	58.84	59.39	59.70	59.38	59.07	59.65	59.87	58.97	59.08
10	58.08	59.97	58.73	58.18	58.93	59.04	59.28	58.55	58.72	60.11	60.31	58.61	59.03
11	58.35	60.26	58.30	57.63	58.63	58.11	58.18	56.92	57.75	60.31	60.56	58.65	58.63
12	58.76	60.47	57.83	56.71	57.87	56.99	56.65	55.87	57.42	60.28	60.85	58.78	58.19
13	59.29	60.76	57.61	55.99	56.93	55.81	55.12	55.81	57.79	60.94	61.46	59.06	58.03
14	59.82	61.45	58.37	56.64	57.49	55.99	55.00	57.72	59.52	62.36	62.81	59.80	58.90
15	60.17	62.03	59.51	57.78	58.96	57.38	56.96	60.23	61.48	63.80	64.22	60.70	60.25
16	60.30	62.40	60.35	58.97	60.47	59.61	58.92	61.82	62.63	64.83	65.39	61.91	61.46
17	60.62	62.87	61.28	60.22	61.73	61.41	60.60	62.89	63.50	65.67	66.41	63.08	62.52
18	61.73	64.03	62.92	61.69	62.86	62.80	62.21	63.78	64.23	66.24	67.29	64.30	63.67
19	63.09	65.16	64.36	63.18	64.02	63.85	63.81	64.49	64.87	66.50	67.86	65.38	64.71
20	64.18	65.92	65.03	63.93	65.21	64.99	64.98	65.02	65.12	66.12	67.47	65.82	65.31
21	64.71	66.41	65.15	63.66	65.49	65.68	65.59	65.61	65.02	65.61	66.75	65.87	65.46
22	65.11	66.77	65.04	62.73	64.64	65.83	65.68	65.41	64.57	64.83	66.01	65.87	65.20
23	65.02	66.99	64.77	62.06	63.66	65.16	65.18	65.09	64.37	64.54	65.70	65.97	64.86
Global	62.60	63.54	61.70	59.99	61.14	61.51	61.68	61.68	61.41	62.40	63.72	63.21	62.04

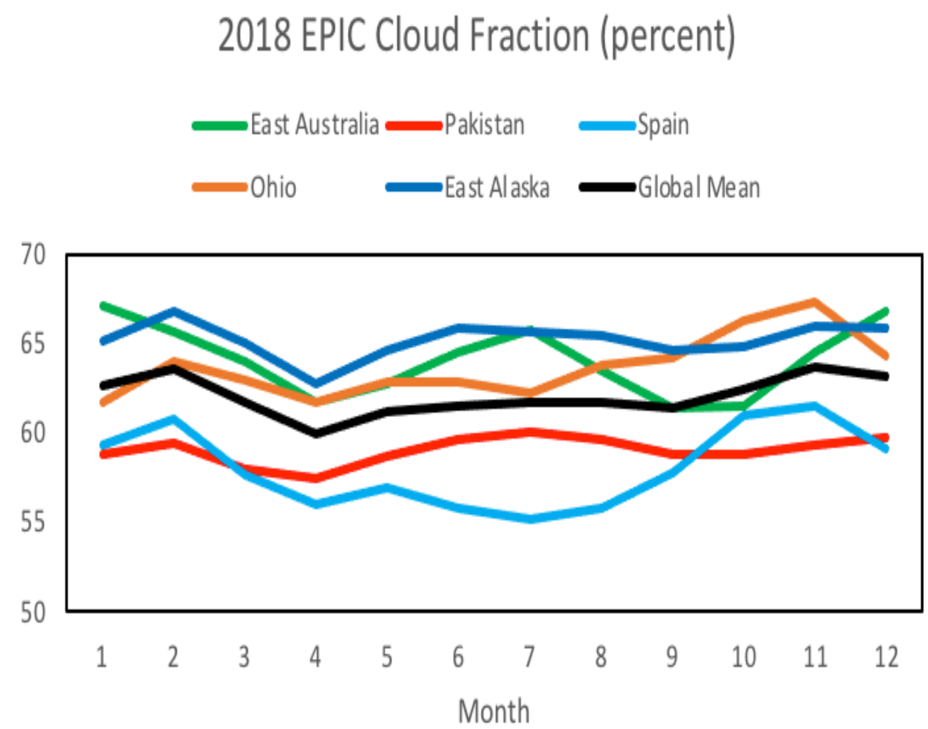
EPIC-Derived: 2018 All-cloud Sky Fraction (std dev)

EPIC-2018 Longitudinal and Seasonal Variability: All-Cloud EPIC Cloud Fraction (UTMon Pt Std Dev)

hourUT	Jan=1	Feb=2	Mar=3	Apr=4	May=5	Jun=6	Jul=7	Aug=8	Sep=9	Oct=10	Nov=11	Dec=12	Annual
0	0.37	0.31	0.39	0.29	0.25	0.28	0.23	0.24	0.24	0.49	0.36	0.48	0.33
1	0.31	0.29	0.36	0.26	0.24	0.26	0.23	0.17	0.21	0.60	0.33	0.40	0.31
2	0.27	0.30	0.37	0.27	0.24	0.28	0.22	0.17	0.21	0.87	0.33	0.39	0.33
3	0.24	0.29	0.36	0.26	0.27	0.28	0.24	0.18	0.19	0.50	0.29	0.38	0.29
4	0.24	0.27	0.33	0.24	0.26	0.27	0.24	0.17	0.18	0.37	0.25	0.35	0.26
5	0.27	0.27	0.29	0.25	0.24	0.24	0.21	0.17	0.18	0.35	0.20	0.31	0.25
6	0.29	0.31	0.26	0.28	0.26	0.25	0.19	0.19	0.22	0.31	0.22	0.30	0.26
7	0.23	0.32	0.28	0.28	0.25	0.22	0.23	0.18	0.24	0.24	0.26	0.28	0.25
8	0.21	0.31	0.27	0.27	0.24	0.23	0.25	0.19	0.25	0.21	0.30	0.26	0.25
9	0.19	0.29	0.26	0.28	0.22	0.25	0.23	0.18	0.22	0.20	0.29	0.30	0.24
10	0.18	0.25	0.27	0.31	0.20	0.23	0.19	0.22	0.21	0.24	0.27	0.35	0.24
11	0.16	0.20	0.19	0.30	0.20	0.22	0.17	0.23	0.23	0.28	0.23	0.36	0.23
12	0.16	0.18	0.16	0.33	0.21	0.22	0.20	0.23	0.27	0.30	0.21	0.33	0.23
13	0.19	0.24	0.18	0.35	0.21	0.25	0.20	0.21	0.32	0.33	0.26	0.31	0.25
14	0.18	0.27	0.21	0.32	0.22	0.26	0.16	0.22	0.30	0.32	0.25	0.29	0.25
15	0.20	0.30	0.28	0.27	0.23	0.28	0.17	0.19	0.30	0.32	0.23	0.28	0.25
16	0.19	0.30	0.27	0.25	0.25	0.30	0.19	0.19	0.35	0.34	0.19	0.24	0.25
17	0.19	0.29	0.28	0.23	0.24	0.33	0.20	0.22	0.38	0.33	0.19	0.23	0.26
18	0.20	0.32	0.27	0.22	0.23	0.36	0.18	0.27	0.37	0.31	0.25	0.24	0.27
19	0.22	0.36	0.27	0.24	0.22	0.34	0.20	0.29	0.36	0.32	0.30	0.26	0.28
20	0.26	0.37	0.28	0.26	0.22	0.31	0.18	0.27	0.36	0.31	0.25	0.30	0.28
21	0.29	0.35	0.28	0.25	0.23	0.30	0.20	0.26	0.32	0.34	0.23	0.36	0.29
22	0.34	0.34	0.31	0.23	0.25	0.31	0.22	0.23	0.27	0.39	0.23	0.41	0.29
23	0.42	0.45	0.41	0.30	0.25	0.29	0.24	0.28	0.30	0.52	0.26	0.49	0.35
Global	0.24	0.30	0.29	0.27	0.23	0.27	0.21	0.21	0.27	0.37	0.26	0.33	0.27

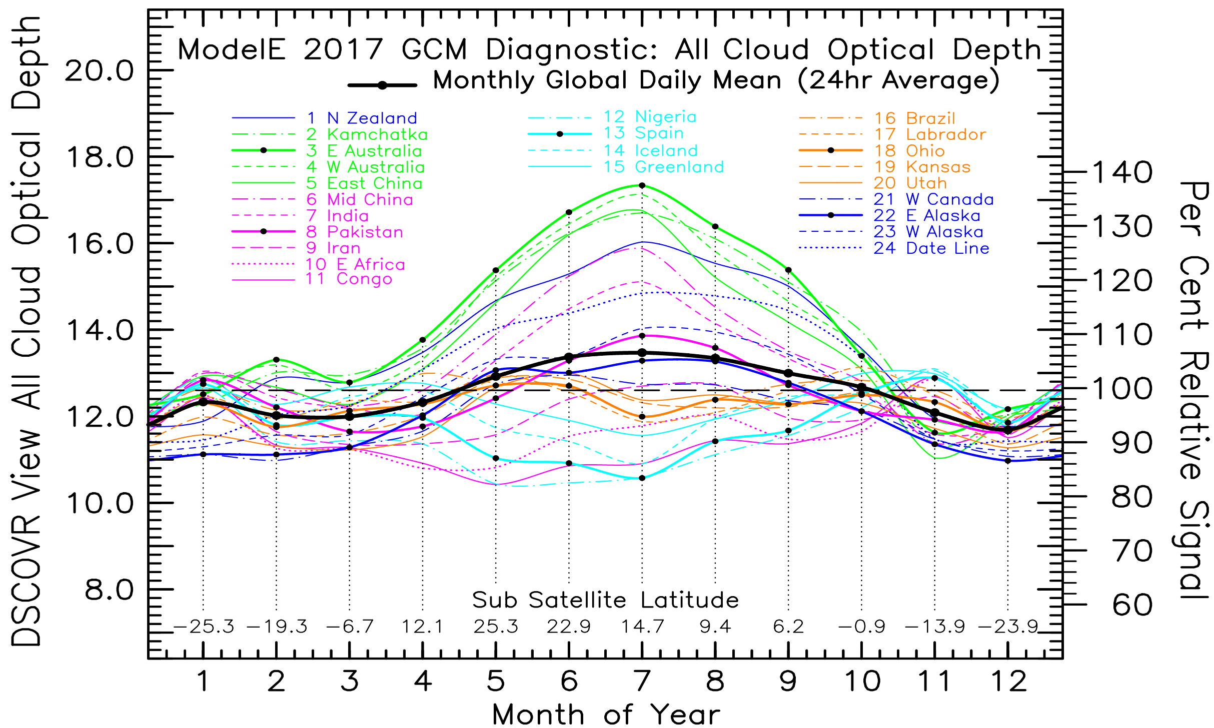
EPIC-Derived 2017 & 2018 All-Cloud Cloudy-sky Fraction (percent)





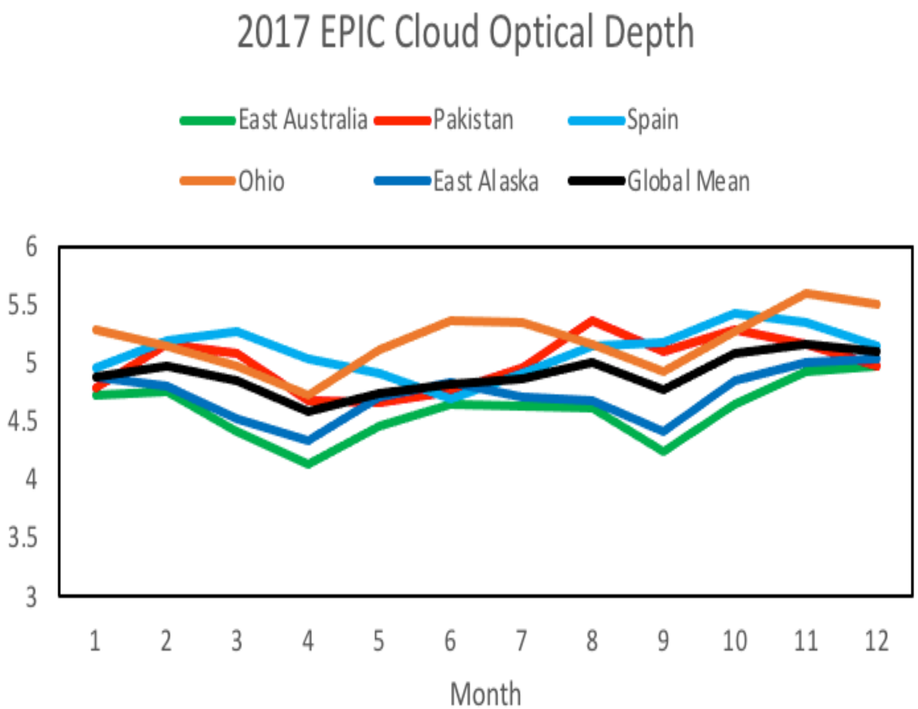
Sampled seasonal spaghetti map of EPIC sunlit hemisphere monthly-mean cloud cover for the years 2017 and 2018. ***Note GCM-EPIC 'relative' similarity*** for maximum May-June-July cloud cover occurring over West Pacific (E Australia-green), next is East Pacific (E Alaska- dark blue). Lowest is over the Atlantic (Spain- blue-green), next up is Asia (Pakistan- magenta). Global-mean seasonal cloud fraction is black, and similar to North America (Ohio- orange). ***However,*** the EPIC seasonal diurnal range is smaller and more uniform than than the GCM, and the is no constricted diurnal range for Nov-Dec-Jan. ***Global-mean EPIC-derived cloud cover is 61.06% for 2017, 62.04% for 2018,*** with modest inter-annual variability.

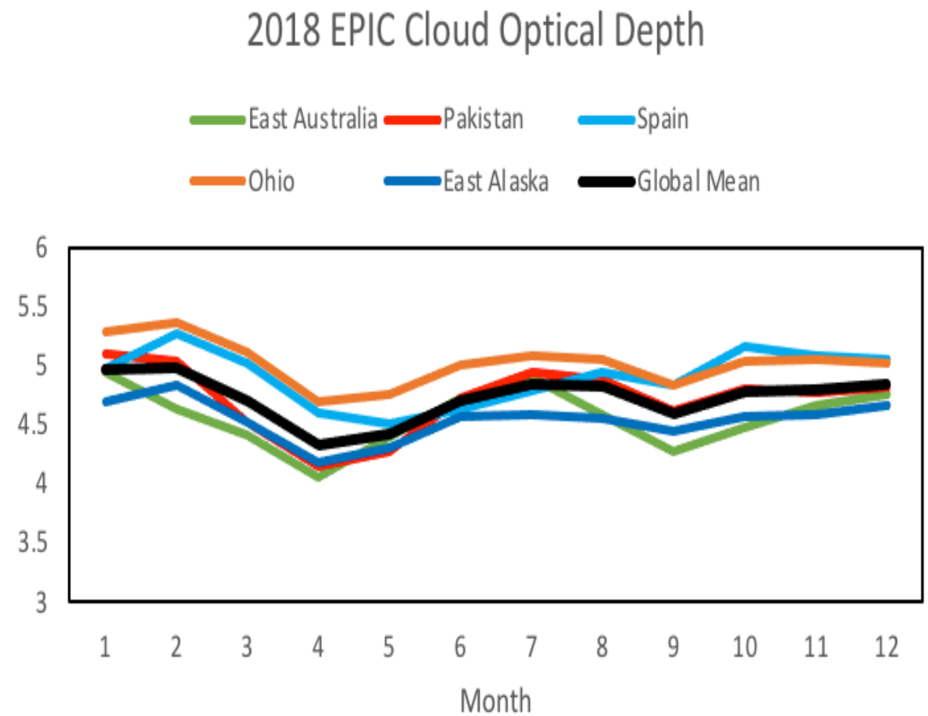
Dayside Hemisphere DSCOVR-View ModelE_2.1 All-Cloud Optical Depth



Seasonal spaghetti map of ModelE2 sunlit EPIC-view hemisphere monthly-mean all-cloud optical depth. The optical depths are condensed liquid water conversions, and thus not the same as heterogeneity modified optical depths used in radiative transfer flux calculations. ***Note:*** Jun-Jul-Aug maximum value occurs over West Pacific (E Australia- green, also N Zealand through China). The minimum is over the Atlantic (Spain- light blue, also Nigeria, Congo). E Pacific and Asia (E Alaska- dark blue and Pakistan- magenta) are close to the global-mean (black). North America (Ohio- orange) is in between the global-mean and the Atlantic value. For October to March, there is a much reduced diurnal variability.

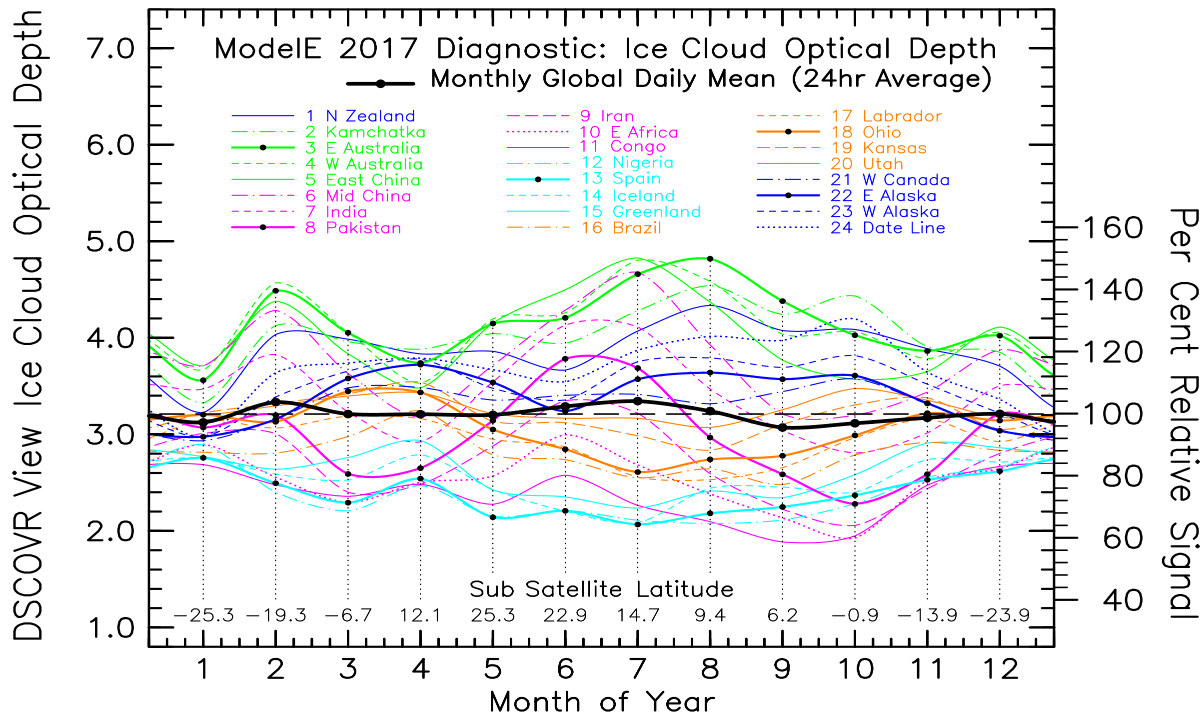
(no resemblance) EPIC-Derived 2017 & 2018 All-Cloud Optical Depth





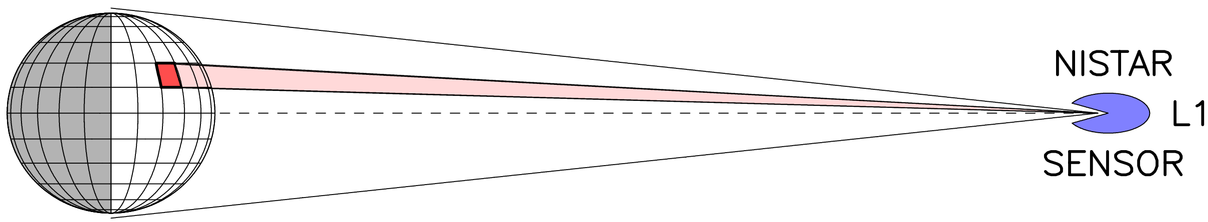
Sampled seasonal spaghetti map of EPIC-derived sunlit hemisphere monthly-mean all-cloud optical depth for the key selected geographical regions (corresponding also to UT = 3, 8, 13, 18, and 22) for the years 2017 and 2018. In comparing to the ModelE results, the lack of correlation confirms the difficulty in comparing model generated and observation retrieved optical depths. The comparison must include full accounting for cloud heterogeneity transformations, and accompanying cloud fraction, cloud particle size and asymmetry parameter/phase function information. With all of those parameters fully accounted for, GCM and EPIC cloud optical depths must agree since both the GCM and EPIC reproduce the same global annual-mean planetary albedo.

Dayside Hemisphere DSCOVR-View ModelE_2.1 Ice-Cloud Optical Depth



Seasonal spaghetti map of ModelE2 sunlit EPIC-view hemisphere monthly-mean all-cloud optical depth. The optical depths are condensed liquid water equivalent conversions, and thus not the same as heterogeneity modified optical depths used in radiative transfer flux calculations. ***Note:*** Jul-Aug maximum value occurs over West Pacific (E Australia- green). A rather flat minimum occurs over the Atlantic (Spain- light blue, also Nigeria, Congo). E Pacific (E Alaska- dark blue) is close to the global-mean (black). North America (Ohio- orange) is in between the global-mean and Atlantic value. Asia (Pakistan- magenta) has more of a more bi-annual seasonal cycle. The GCM ice cloud optical depth does not include heterogeneity transformation.

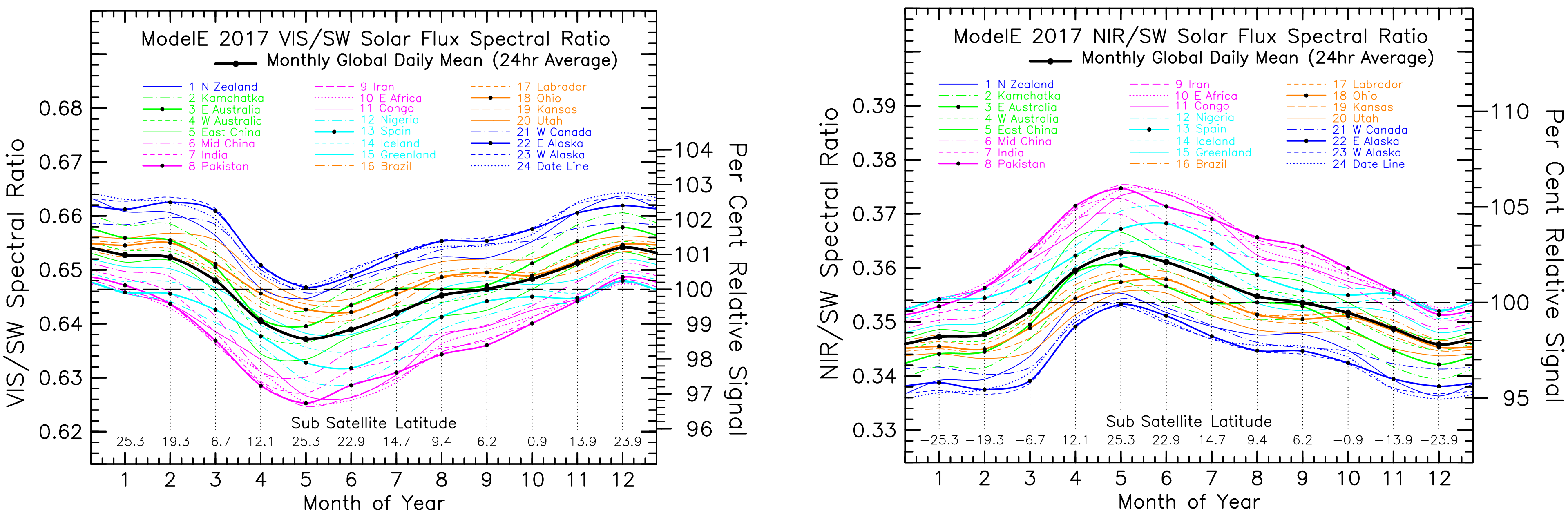
NISTAR Measurements *vs* ModelE2.1 Vis/NIR Results



Band-A	Band-B	Band-C	Band-D (diode)
(0.2 – 100μm)	(0.2 – 4.0μm)	(0.7 – 4.0μm)	(0.3 – 1.1μm)
TOR (SW+LW)	**RSR** (Vis)	**near-IR**	**Vis** (cal)

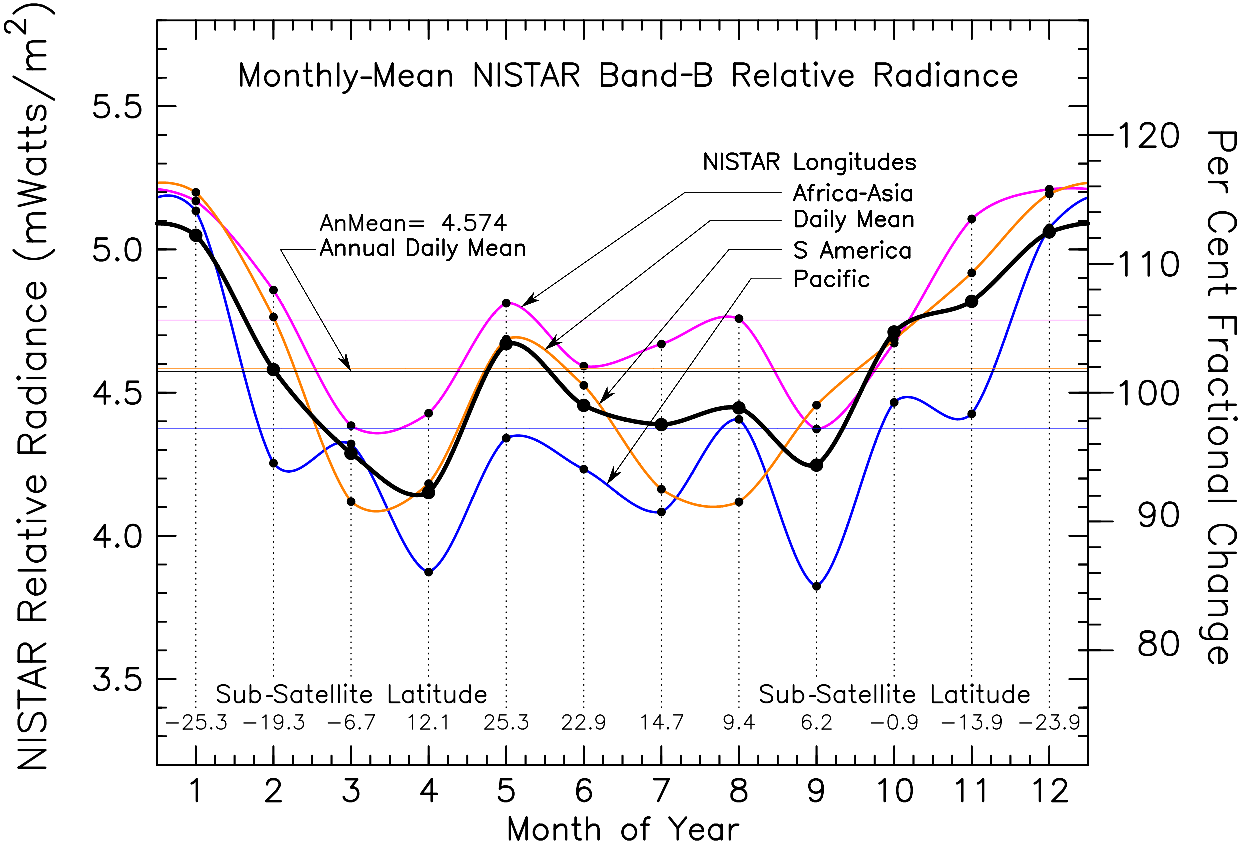
Active Cavity Radiometers **Photodiode**

DSCOVR-View ModelE_2.1 VIS/SW & NIR/SW Spectral Ratio



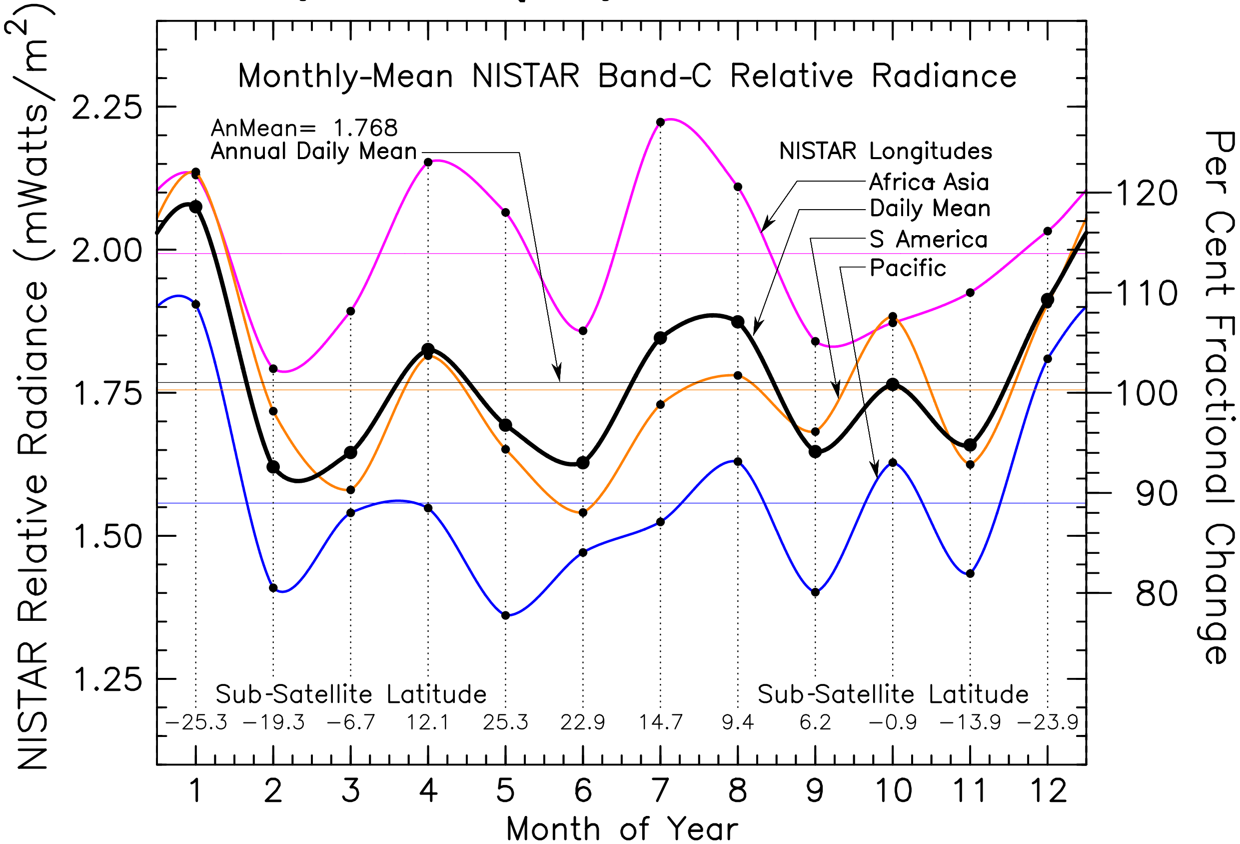
Seasonal spaghetti map of dayside hemisphere VIS/SW (left panel) and NIR/SW (right panel) broad-band spectral ratio of reflected SW solar radiation, color-code for every 15 degrees of longitude, and tagged with the UT hr (for local noon-time Sun) and the corresponding geographical location.

NISTAR Band-B (0.2 – 4.0μm) (VIS+NIR) Total SW Relative Radiance



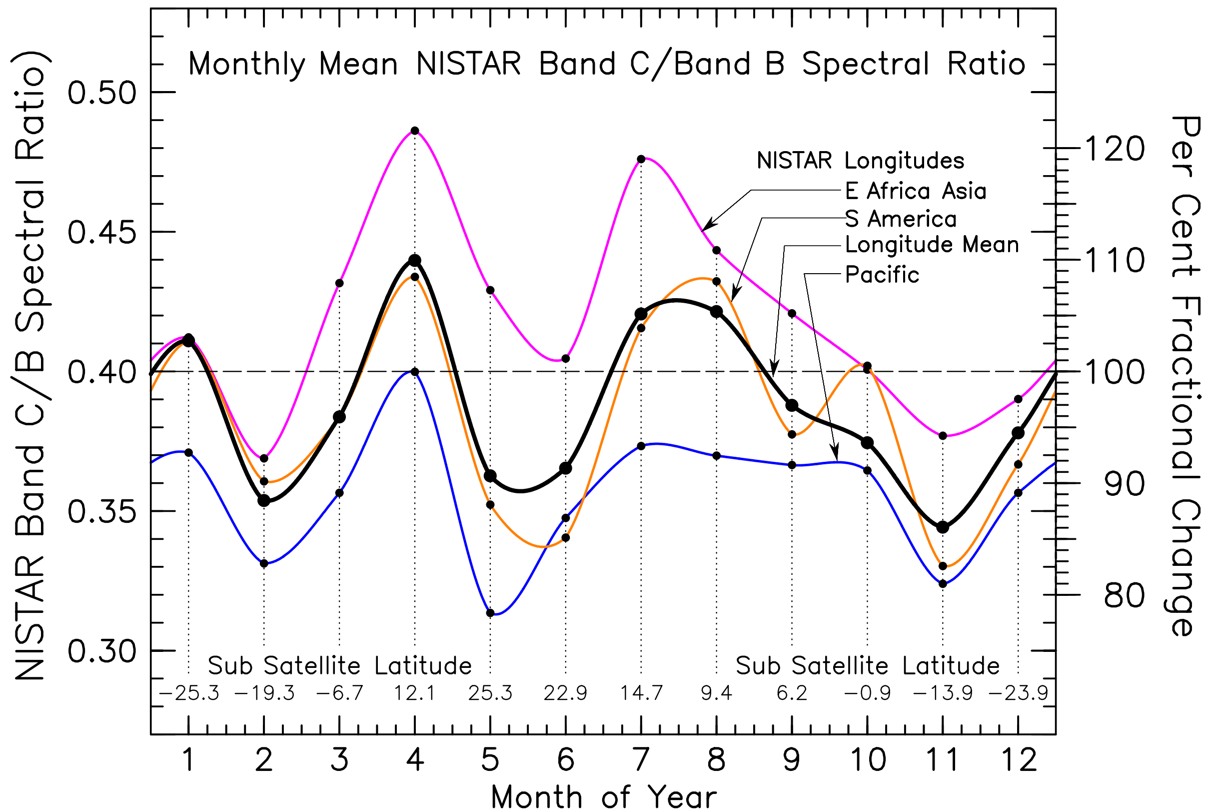
NISTAR Band-B measurement of seasonal change in total (VIS+NIR) SW radiance reflected from the dayside hemisphere for selected longitudes of noon-time Sun. Solid black curve is daily average over all longitudes.

NISTAR Band-C (0.7 – 4.0μm) NIR SW Relative Radiance



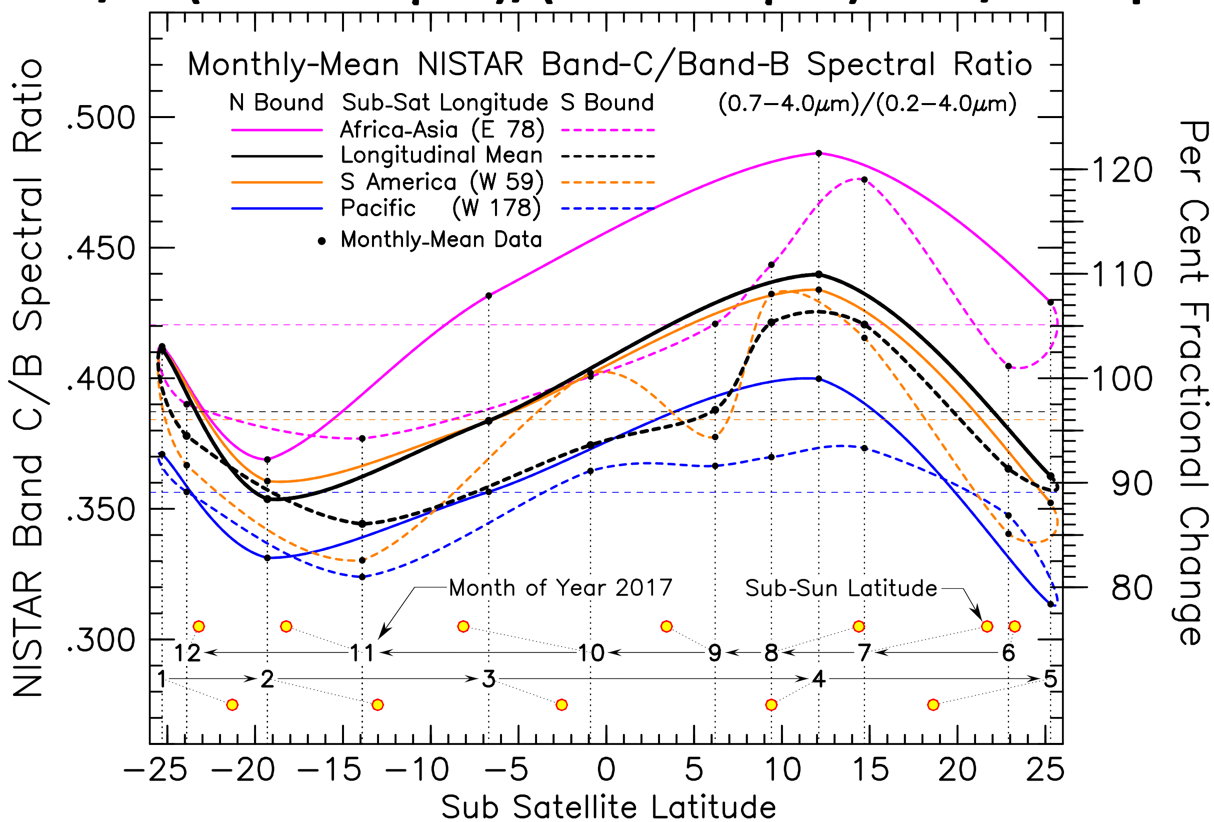
NISTAR Band-C measurement of seasonal change for NIR SW radiance reflected from the dayside hemisphere for selected longitudes of noon-time Sun. Solid black curve is daily average over all longitudes.

NISTAR Bands-C/B (0.7 – 4.0μm)/(0.2 – 4.0μm) NIR/SW Spectral Ratio



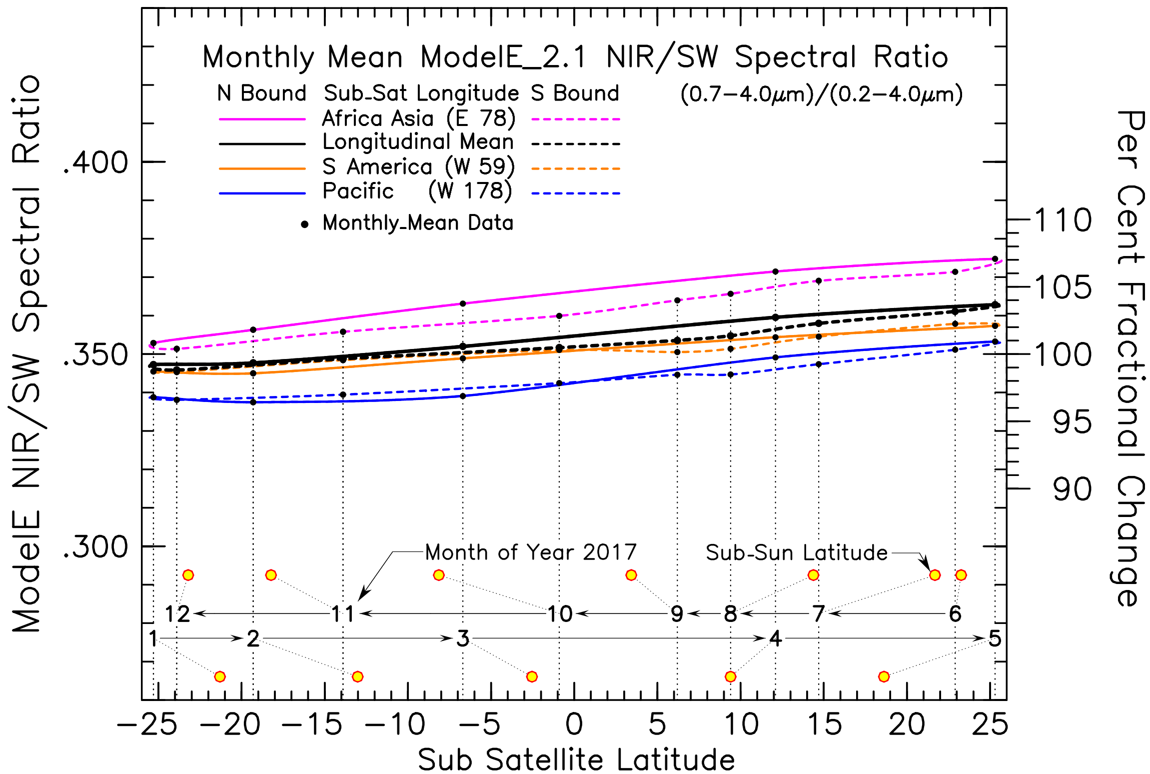
Seasonal spaghetti map of NISTAR Band-C / Band-B spectral ratio of the NIR/SW radiance reflected from the dayside hemisphere for selected longitudes of noon-time Sun. Solid black curve is daily average over all longitudes.

NISTAR Bands-C/B (0.7 – 4.0μm)/(0.2 – 4.0μm) NIR/SW Spectral Ratio



Pinwheel-format diagram of NISTAR Band-C / Band-B spectral ratio of the NIR/SW radiance reflected from the dayside hemisphere for selected longitudes of noon-time Sun. Solid black curve is daily average over all longitudes. At figure bottom, position of sub-solar latitude is shown relative to each monthly-mean position depicted in sub-satellite latitude.

ModelE_2.1 (0.7 – 4.0μm)/(0.2 – 4.0μm) NIR/SW Spectral Ratio



Corresponding pinwheel diagram of the ModelE NIR/SW spectral ratio. The ModelE_2.1 pinwheel diagram has a ***qcualitative orrespondence*** to the NISTAR measurements in terms of its relative longitudinal dependence, but comes nowhere close to having the seasonal and longitudinal NIR/SW spectral variability that is seen in the NISTAR measurements. This comparison with NISTAR suggests significant deficiencies in GCM spectral treatment.

Conclusions

1. NASA's DSCOVR Mission ***EPIC and NISTAR data provide a new and unique diagnostic perspective*** for assessing global climate model performance.
2. EPIC narrow-band, high spatial resolution images of the Earth's sunlit hemisphere provide continuous monitoring of climate system processes.
3. NISTAR near-backscatter SW, NIR broad-band and SW+LW total-spectrum radiances of the unresolved Earth seek to address global energy balance.
4. ***NISTAR data are unique for their NIR/SW spectral ratio diagnostic capability*** for assessing global climate model radiative transfer spectral treatment.
5. DSCOVR measurements have ***direct relevance to exoplanet investigations***.
6. NISTAR spectral ratio time series can deduce exoplanet rotation period, and cloud and vegetation/surface-type distribution and their seasonal variability.
7. EPIC imagery serves to validate inferences from NISTAR spectral ratio data.