# Validation of MODTRAN Off-Earth View Radiances

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## Objective

1. Estimate the uncertainty in irradiances caused by a spherical atmosphere.

## Method

1. Compare modeled radiance by MODTRAN and observed radiance by the CERES instrument at large view zenith angles ($\theta > 80°$ when alt. $\approx$ 100km).
2. Define $\eta$ such that

$$\eta = \frac{I^0_{pf}(\mu, \mu_0)}{I^0_{pf}(\mu_t, \mu_0)}. \tag{1}$$

Then the unfiltered irradiance $F_p(\mu_0)$ is

$$F_p(\mu_0) = 2\pi I^0_{pf}(\mu_t, \mu_0) \int_0^1 \mu \frac{I^0_p(\mu, \mu_0)}{I^0_{pf}(\mu, \mu_0)} \eta d\mu, \tag{2}$$

where $\mu_t$ is the view zenith angle tangent to the surface of the earth, $\frac{I^0_p(\mu,\mu_0)}{I^0_{pf}(\mu,\mu_0)}$ is the ratio of the unfiltered radiance to the filtered radiance and $I^0_{pf}(\mu, \mu_0)$ is the point spread function weighted filtered radiance averaged over azimuth angles defined as

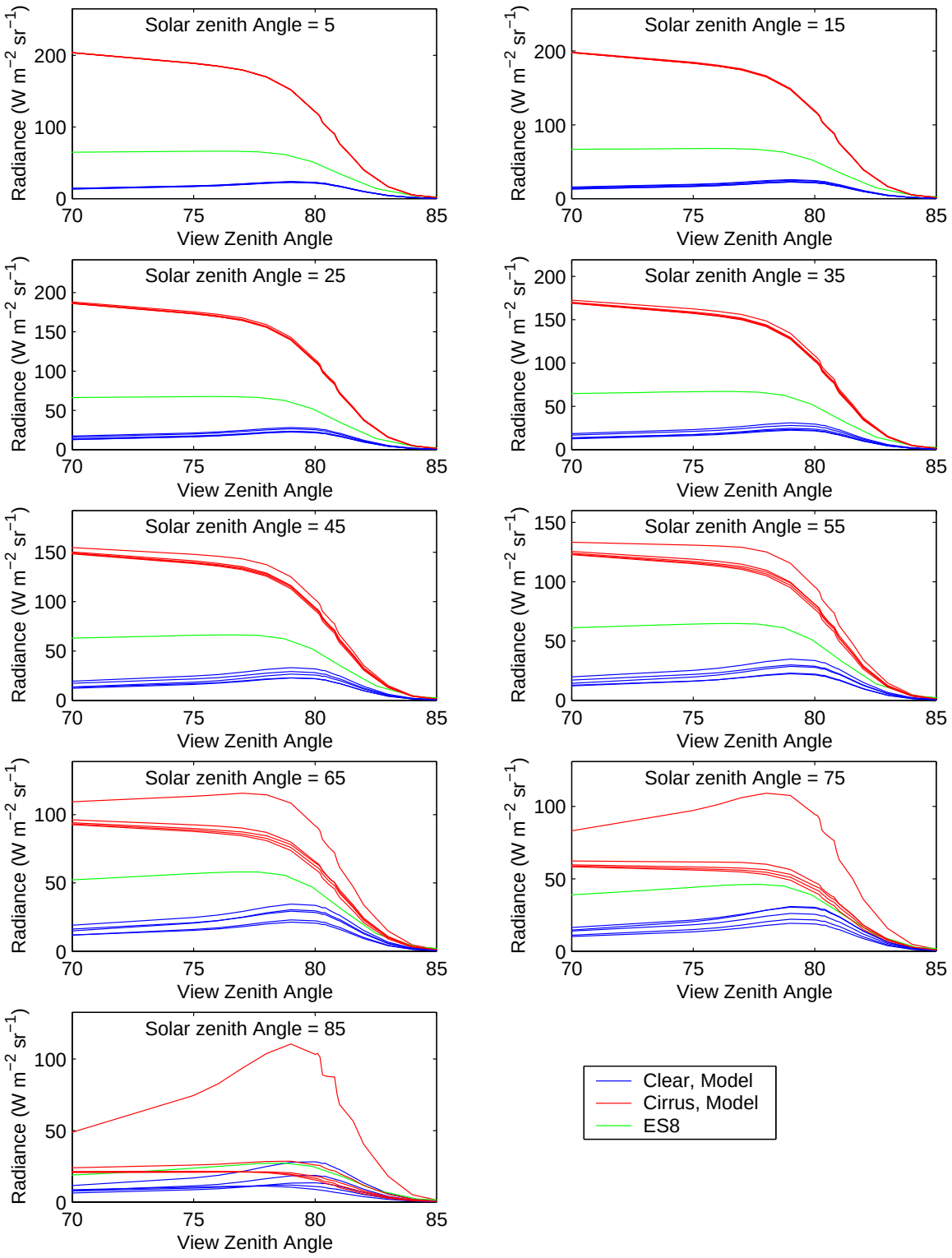
$$I^0_{pf}(\mu, \mu_0) = \frac{1}{2\pi} \int_0^{2\pi} \int_{\mu-\delta}^{\mu+\delta} f(\mu') I_f(\mu, \mu_0) d\mu' d\phi. \tag{3}$$

3. Estimate the variation in $F_p(\mu_0)$ due to the variation in $\eta$.
4. Estimate the difference between $F_p(\mu_0)$ and $F(\mu_0)$ where

$$F(\mu_0) = 2\pi \int_0^1 \mu I^0(\mu, \mu_0) d\mu, \tag{4}$$

where $I^0$ is the radiance averaged over azimuth angles

$$I^0(\mu, \mu_0) = \frac{1}{2\pi} \int_0^{2\pi} I(\mu, \phi, \mu_0) d\phi. \tag{5}$$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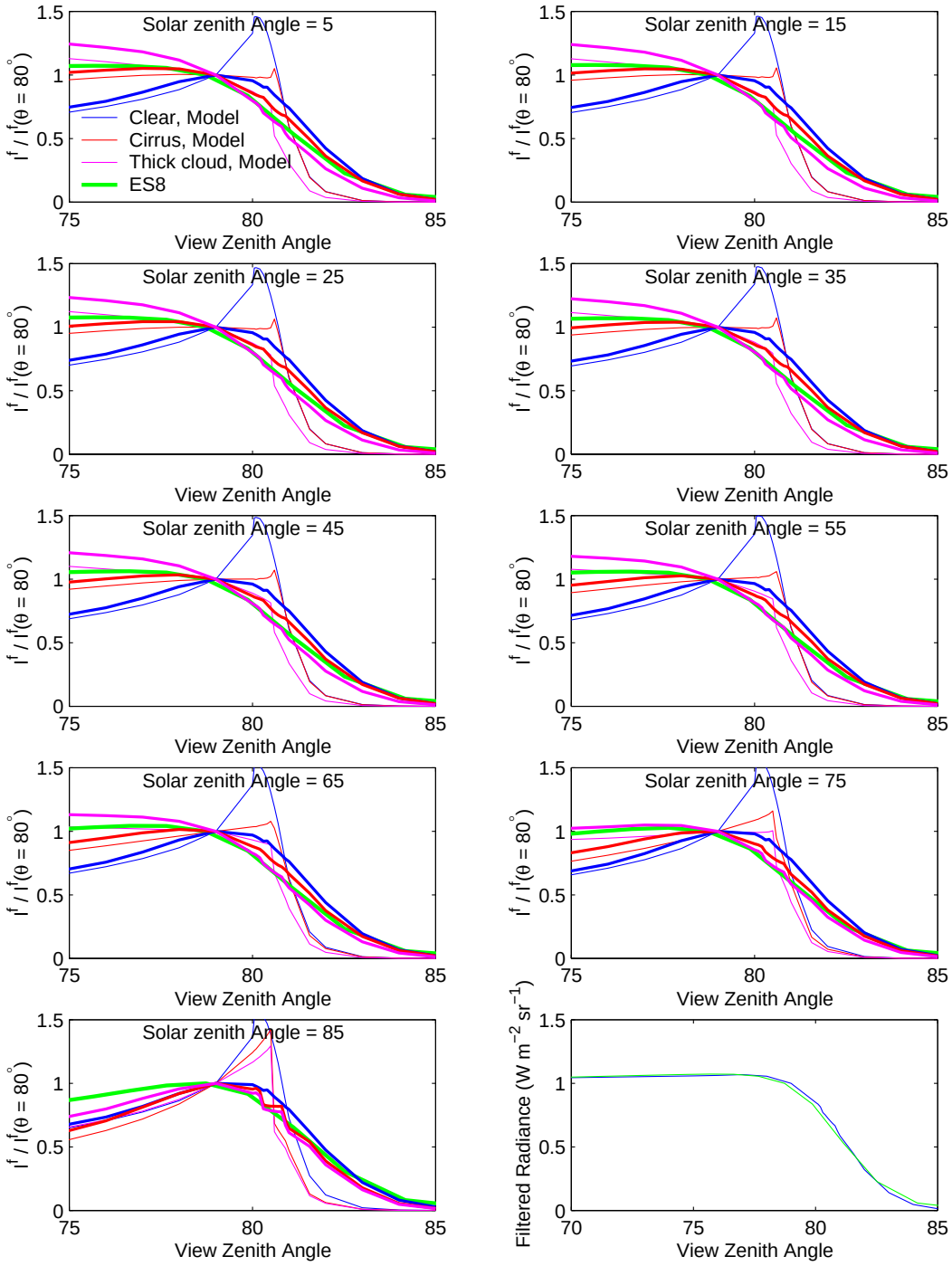
Solar zenith Angle = 15
Solar zenith Angle = 25
Solar zenith Angle = 35
Solar zenith Angle = 45
Solar zenith Angle = 55
Solar zenith Angle = 65
Solar zenith Angle = 75
Solar zenith Angle = 85
Radiance (W m$^{-2}$ sr$^{-1}$)
View Zenith Angle
Clear, Model
Cirrus, Model
ES8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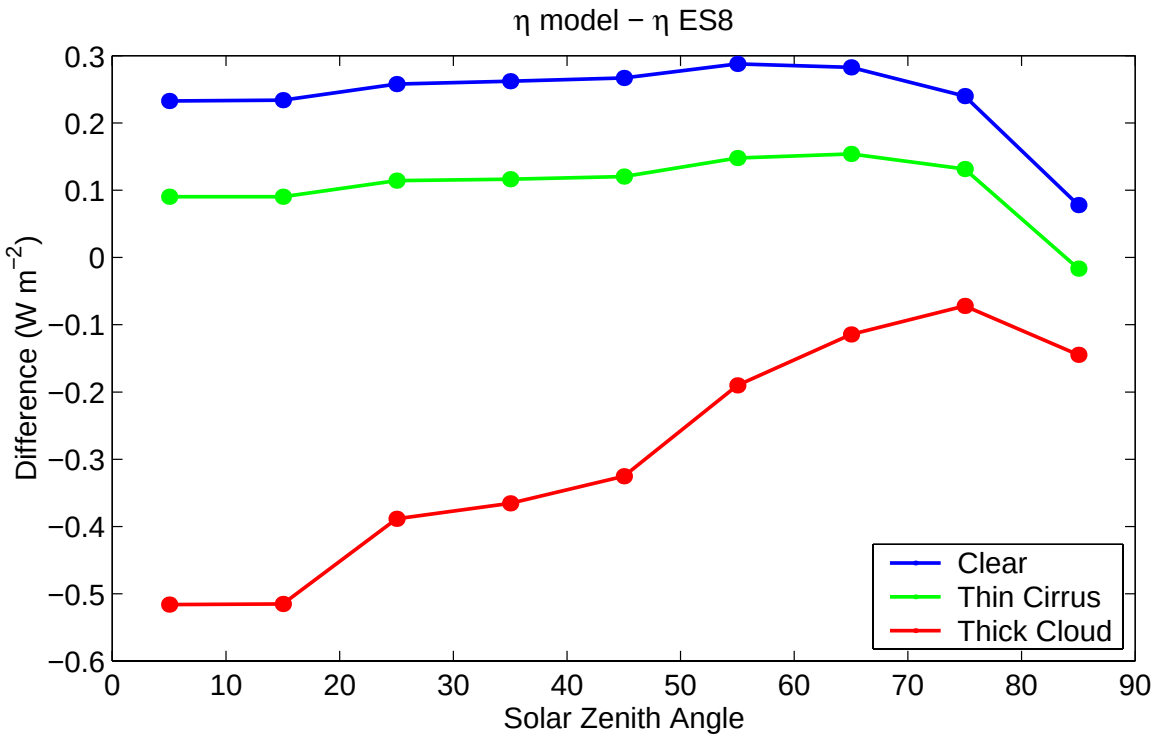
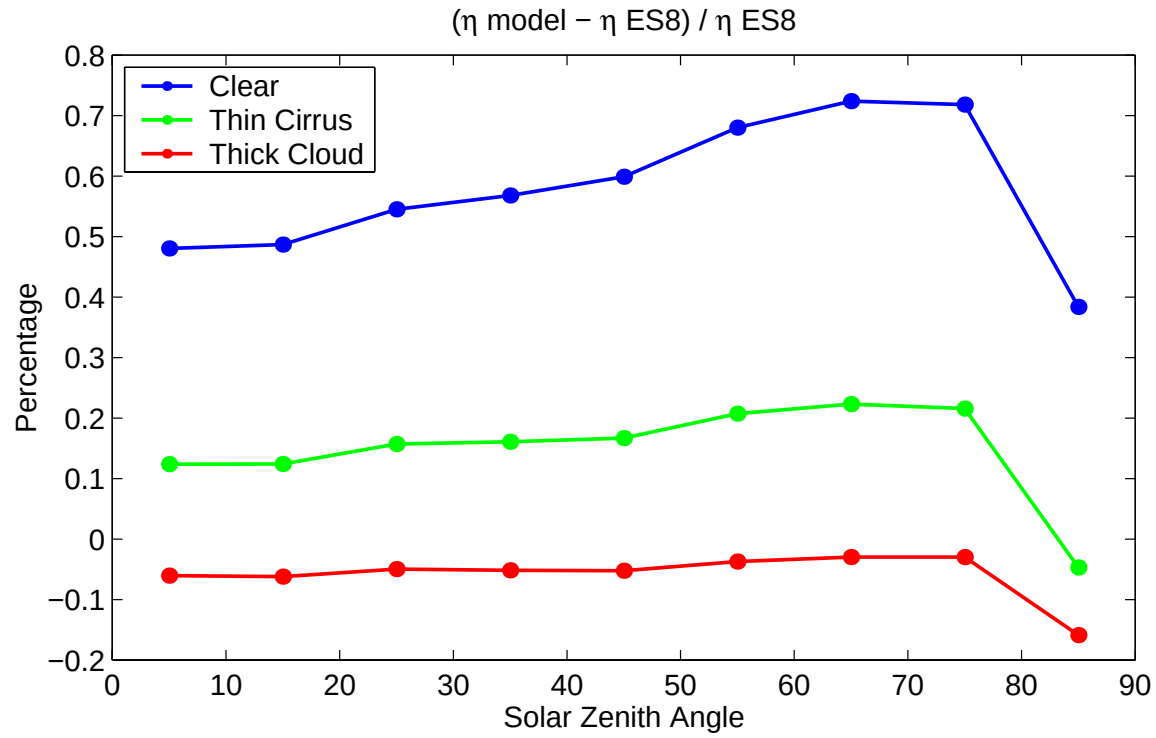
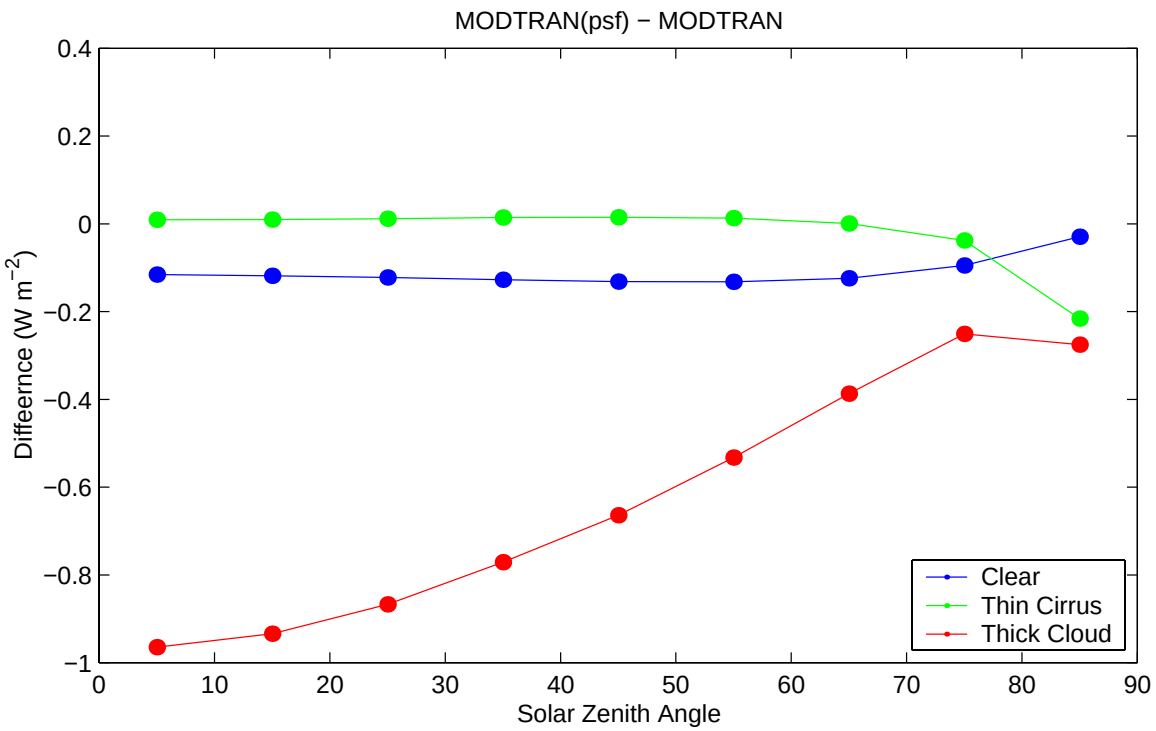
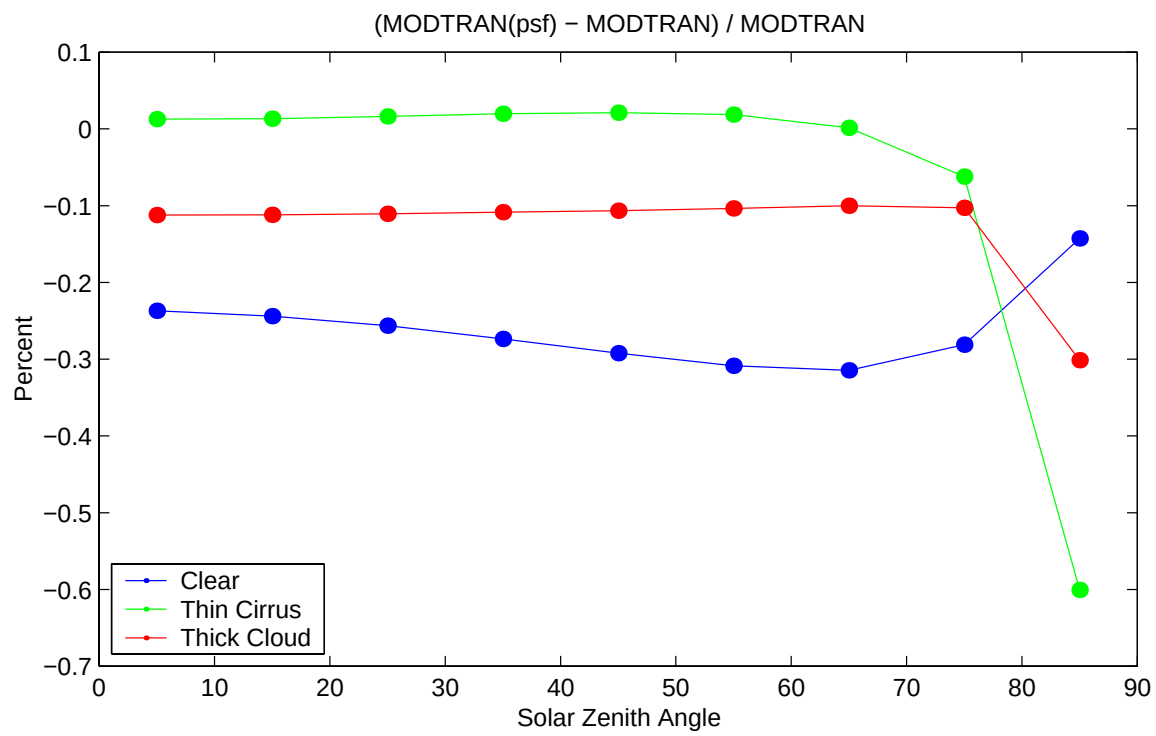
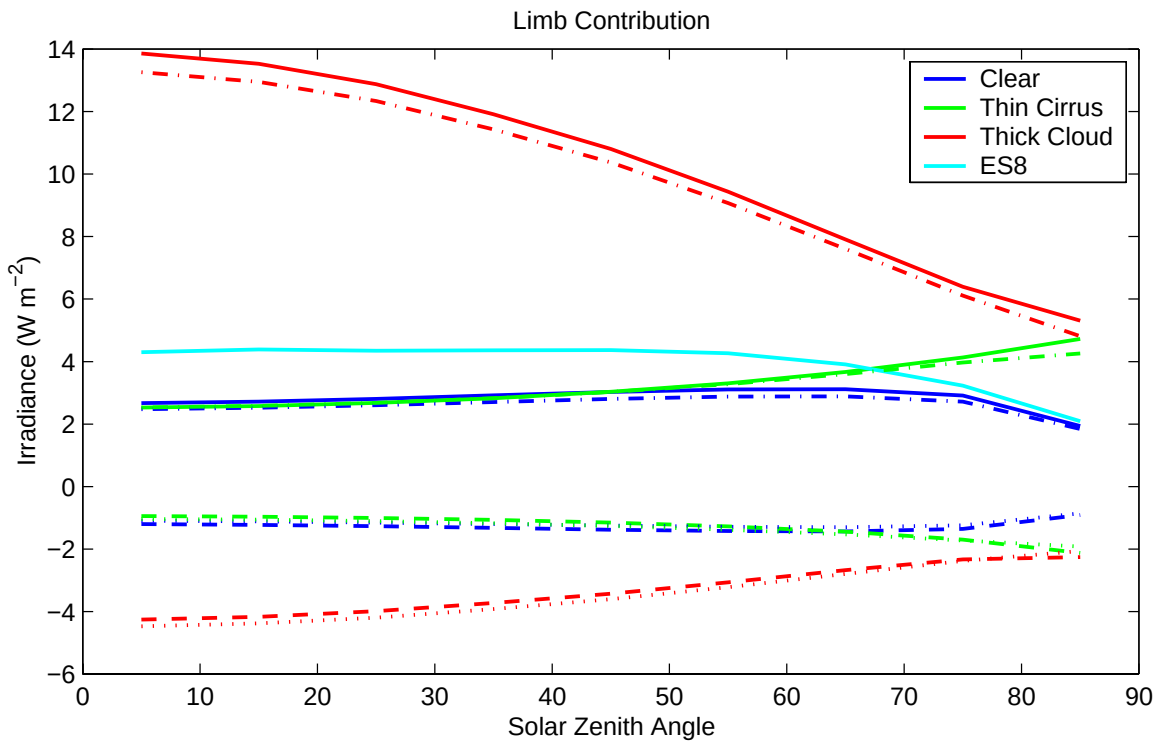
Solar zenith Angle = 45
Solar zenith Angle = 55
Solar zenith Angle = 65
Solar zenith Angle = 75
Solar zenith Angle = 85
Clear, Model
Cirrus, Model
Thick cloud, Model
ES8
$I^f / I^f(\theta = 80^\circ)$
View Zenith Angle
Filtered Radiance (W m$^{-2}$ sr$^{-1}$)
0
0.5
1
1.5
70
75
80
85

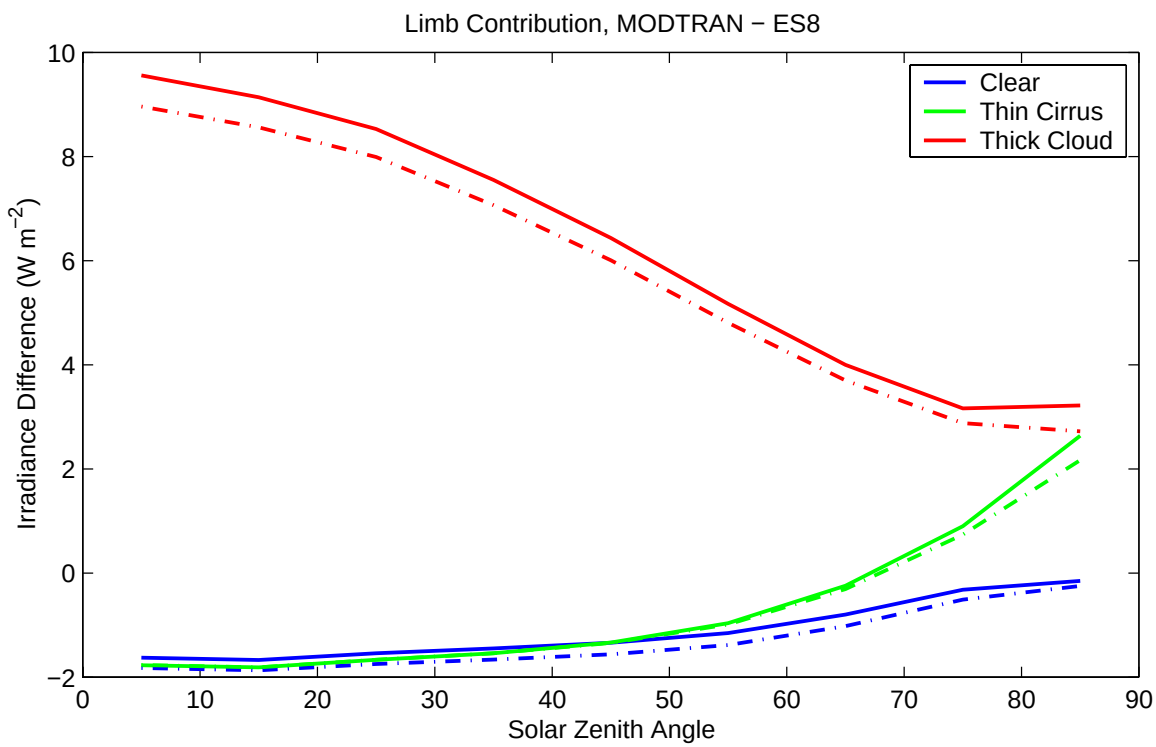

η model − η ES8
Difference (W m$^{-2}$)
Solar Zenith Angle
Clear
Thin Cirrus
Thick Cloud
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
0
10
20
30
40
50
60
70
80
90

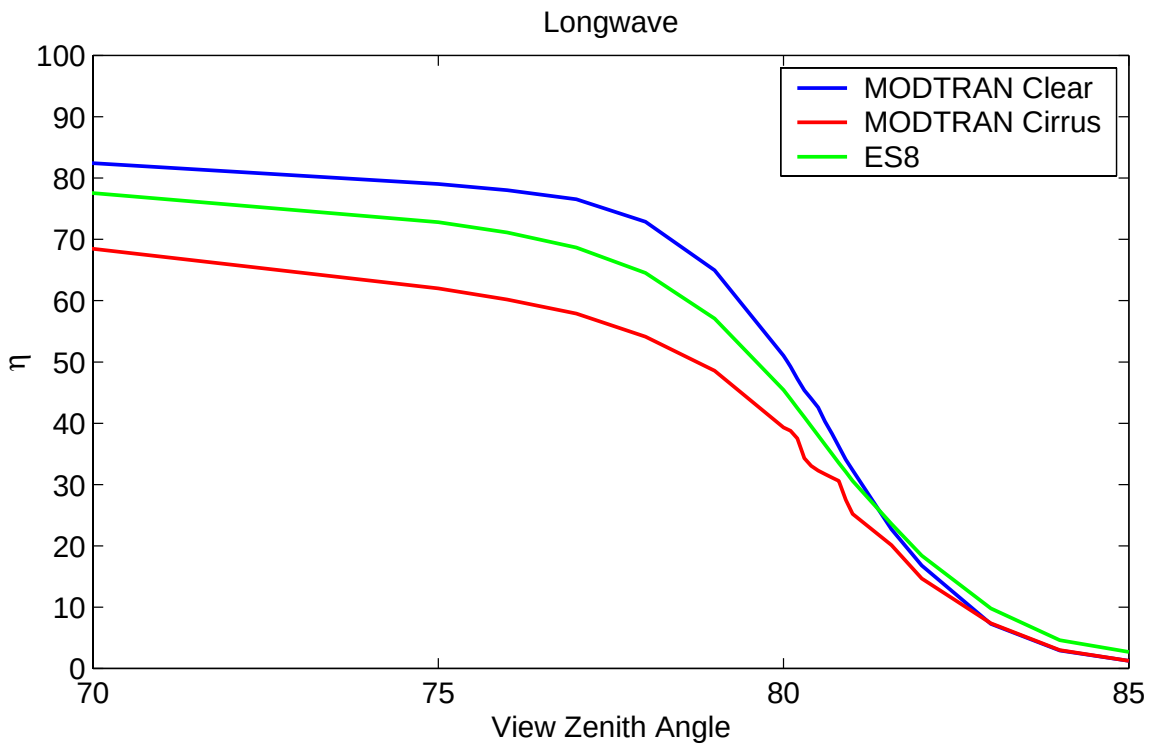

(η model − η ES8) / η ES8
Percentage
Solar Zenith Angle
Clear
Thin Cirrus
Thick Cloud
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
0
10
20
30
40
50
60
70
80
90

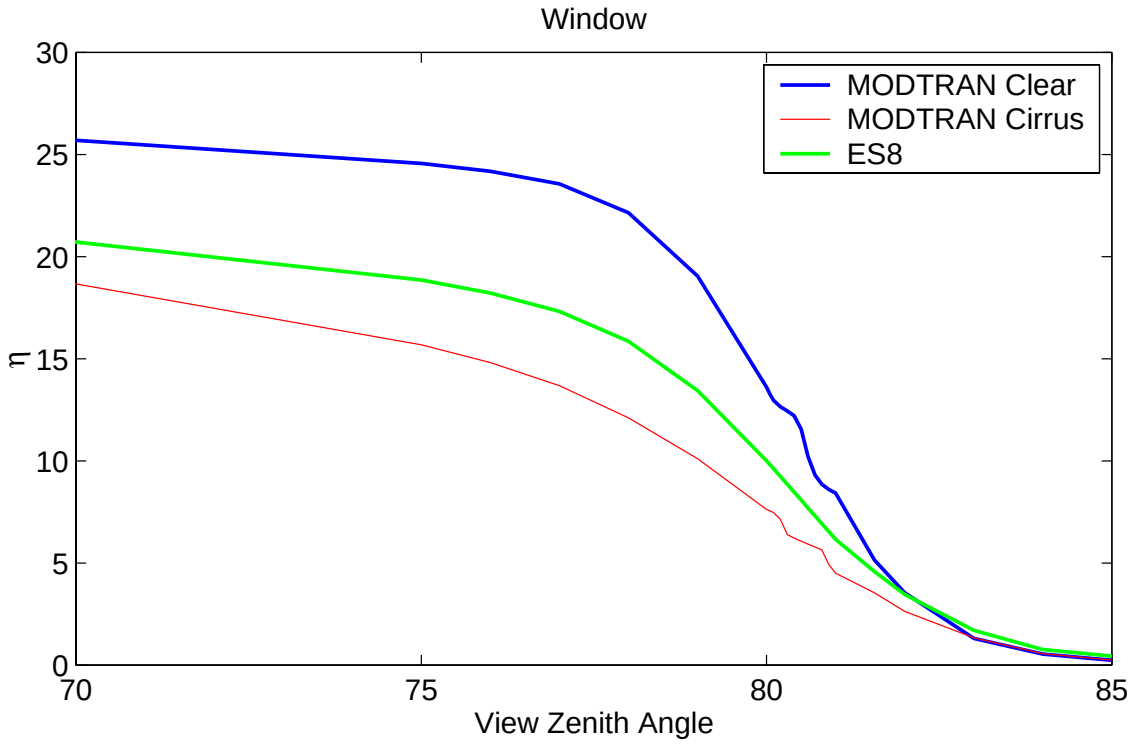

MODTRAN(psf) − MODTRAN
Diffeernce (W m$^{-2}$)
Solar Zenith Angle
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
0
10
20
30
40
50
60
70
80
90
Clear
Thin Cirrus
Thick Cloud


(MODTRAN(psf) − MODTRAN) / MODTRAN
Percent
Solar Zenith Angle
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
0
10
20
30
40
50
60
70
80
90
Clear
Thin Cirrus
Thick Cloud


Limb Contribution
Clear
Thin Cirrus
Thick Cloud
ES8
Irradiance (W m$^{-2}$)
Solar Zenith Angle
14
12
10
8
6
4
2
0
−2
−4
−6
0
10
20
30
40
50
60
70
80
90


Limb Contribution, MODTRAN − ES8
Clear
Thin Cirrus
Thick Cloud
Irradiance Difference (W m$^{-2}$)
Solar Zenith Angle
10
8
6
4
2
0
−2
0
10
20
30
40
50
60
70
80
90


Longwave
MODTRAN Clear
MODTRAN Cirrus
ES8
η
View Zenith Angle
0
10
20
30
40
50
60
70
80
90
100
70
75
80
85


Window
MODTRAN Clear
MODTRAN Cirrus
ES8
η
View Zenith Angle
0
5
10
15
20
25
30
70
75
80
85

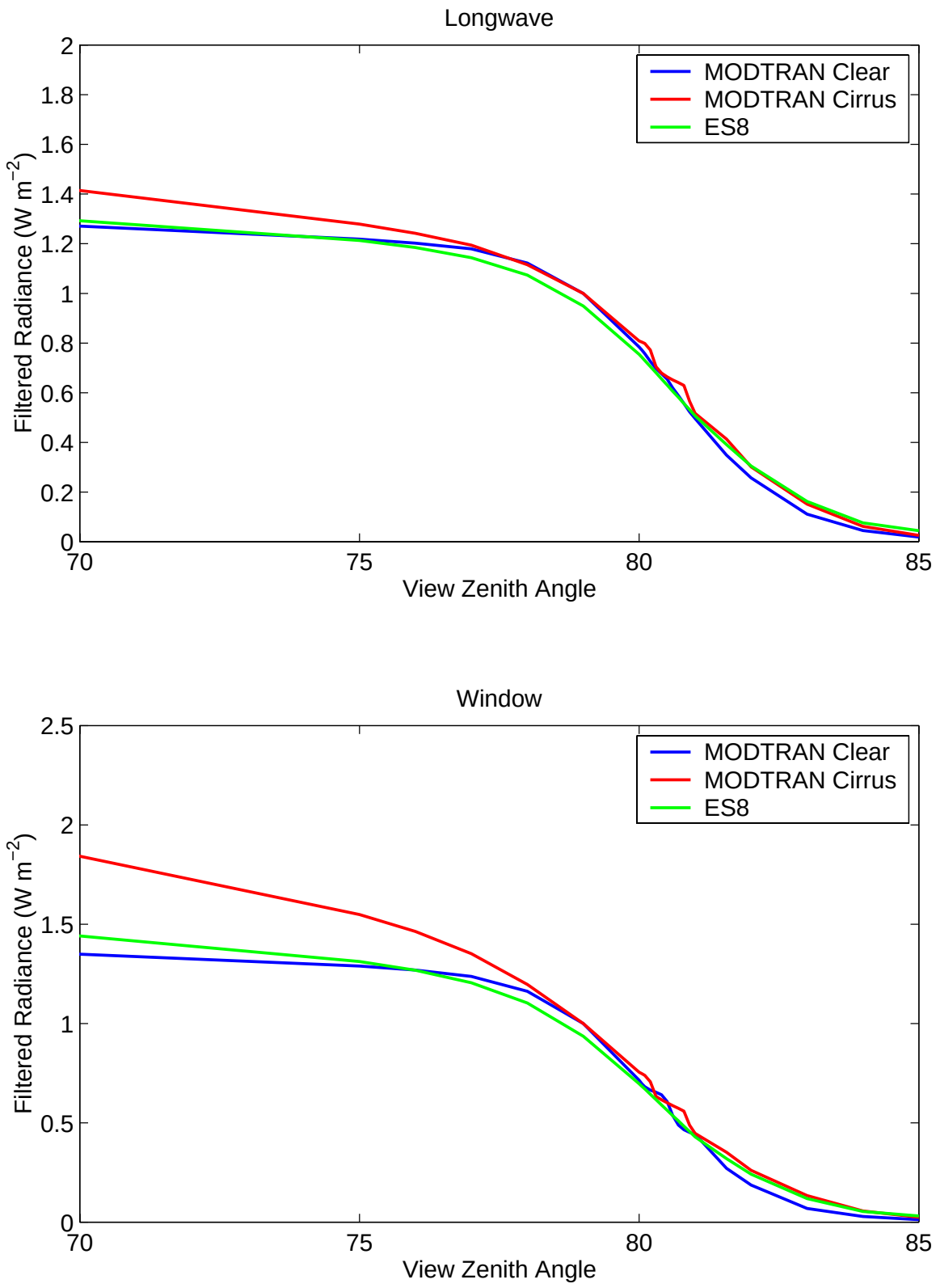
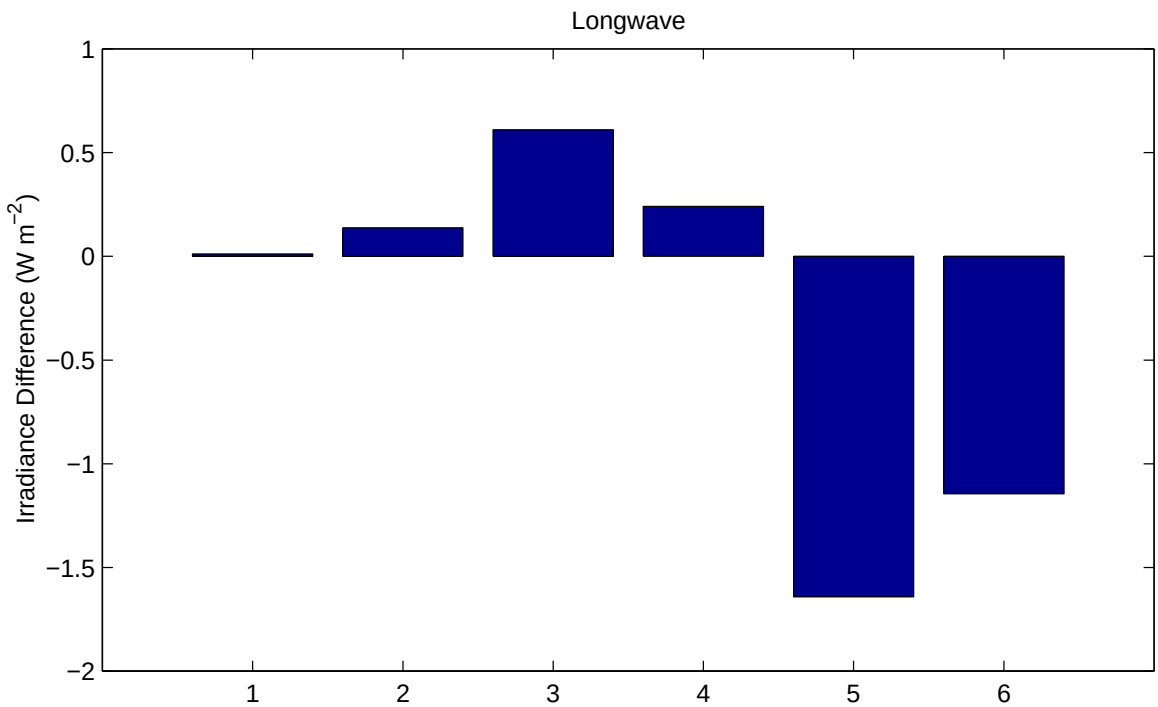
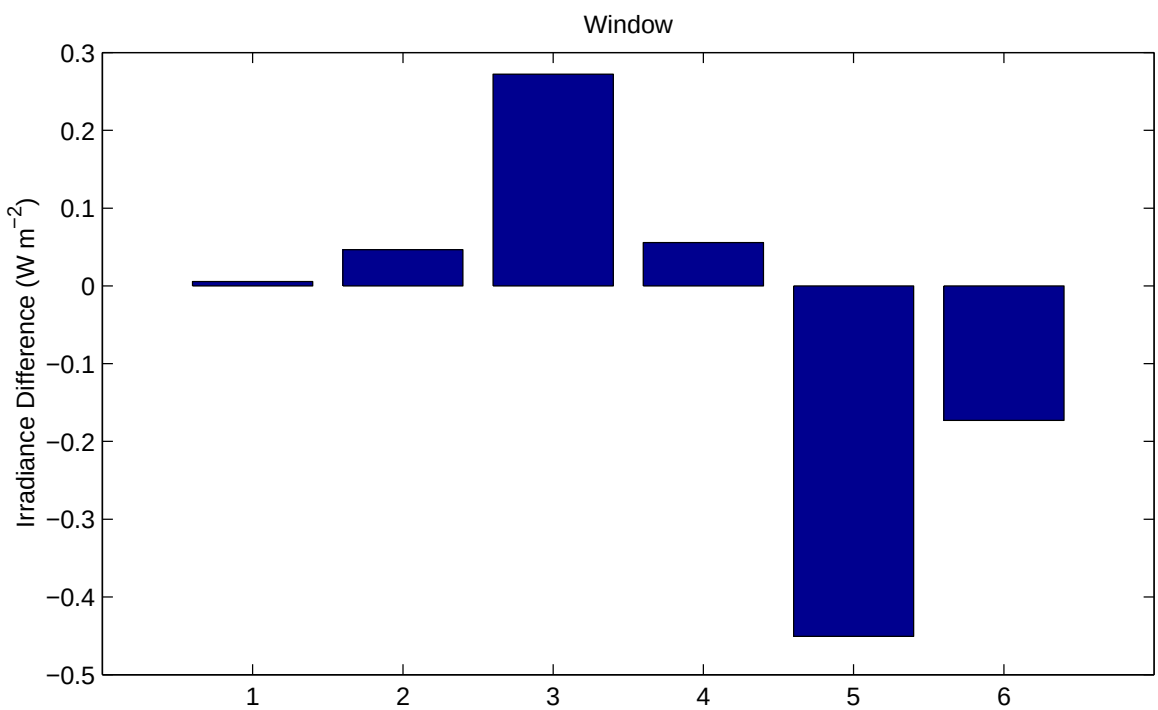

Longwave
MODTRAN Clear
MODTRAN Cirrus
ES8
Filtered Radiance (W m$^{-2}$)
View Zenith Angle
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
70
75
80
85
Window
MODTRAN Clear
MODTRAN Cirrus
ES8
Filtered Radiance (W m$^{-2}$)
View Zenith Angle
0
0.5
1
1.5
2
2.5
70
75
80
85

**Figure 7**




1. $F_{psf}$ clear - ES8, 2. $F_{psf}$ cirrus - ES8,
3. F clear - $F_{psf}$ clear, 4. F cirrus - $F_{psf}$ cirrus
5. $\theta > \theta_t$ clear, 6. $\theta > \theta_t$ cirrus.

## Conclusions

The difference in the unfiltered irradiance using MODTRAN off-earth view radiances from that using the mean ES8-derived off-earth view radiances is

**Shortwave**

less than $0.3\,\mathrm{Wm}^{-2}$ for clear sky, $0.2\,\mathrm{Wm}^{-2}$ for cirrus and $0.6\,\mathrm{Wm}^{-2}$ for a thick cloud.

**Longwave**

less than $0.2\,\mathrm{Wm}^{-2}$.

**Window**

less than $0.1\,\mathrm{Wm}^{-2}$.