CLIM 301
Atmospheric Radiation

Every physical body spontaneously and continuously emits electromagnetic radiation.

Electromagnetic Radiation

- Kirchoff law: absorbed = emitted radiation (when in thermal equilibrium)
- Stefan-Boltzmann Law: total energy radiated by a “black body” is related to T^4
- Planck’s Law: gives radiance as a function of T and frequency or wavelength (for blackbody in thermal equilibrium).

Planck's Function

$$E_{(\lambda,T)} = \frac{2hc^2}{\lambda^5 (e^{\frac{hc}{\lambda kT}} - 1)} * 10^{-6} \quad \mathrm{Wm^{-2}sr^{-1}\mu m^{-1}}$$

$$E(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{hc/\lambda kT} - 1}$$

$h = 6.625 \times 10^{-27}$ erg- sec (Planck Constant)

$k = 1.38 \times 10^{-16}$ erg/ K (Boltzmann Constant)

$c = 3 \times 10^{10}$ cm/sec (Speed of Light)

Steffan - Boltzmann Law:

$$E = \sigma T^4$$

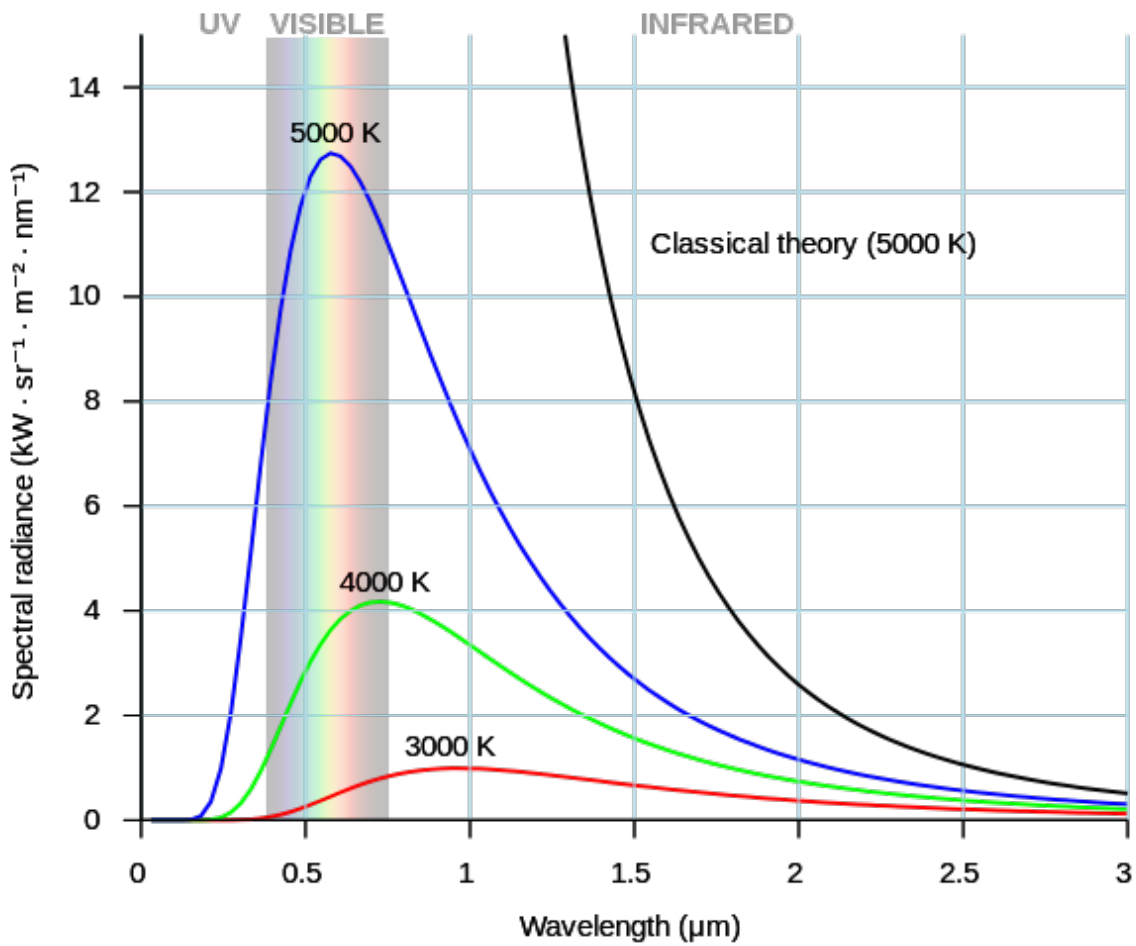
$\sigma = 5.6705 \times 10^{-5}$ erg - cm^{-2} - K^{-4} - sec^{-1}

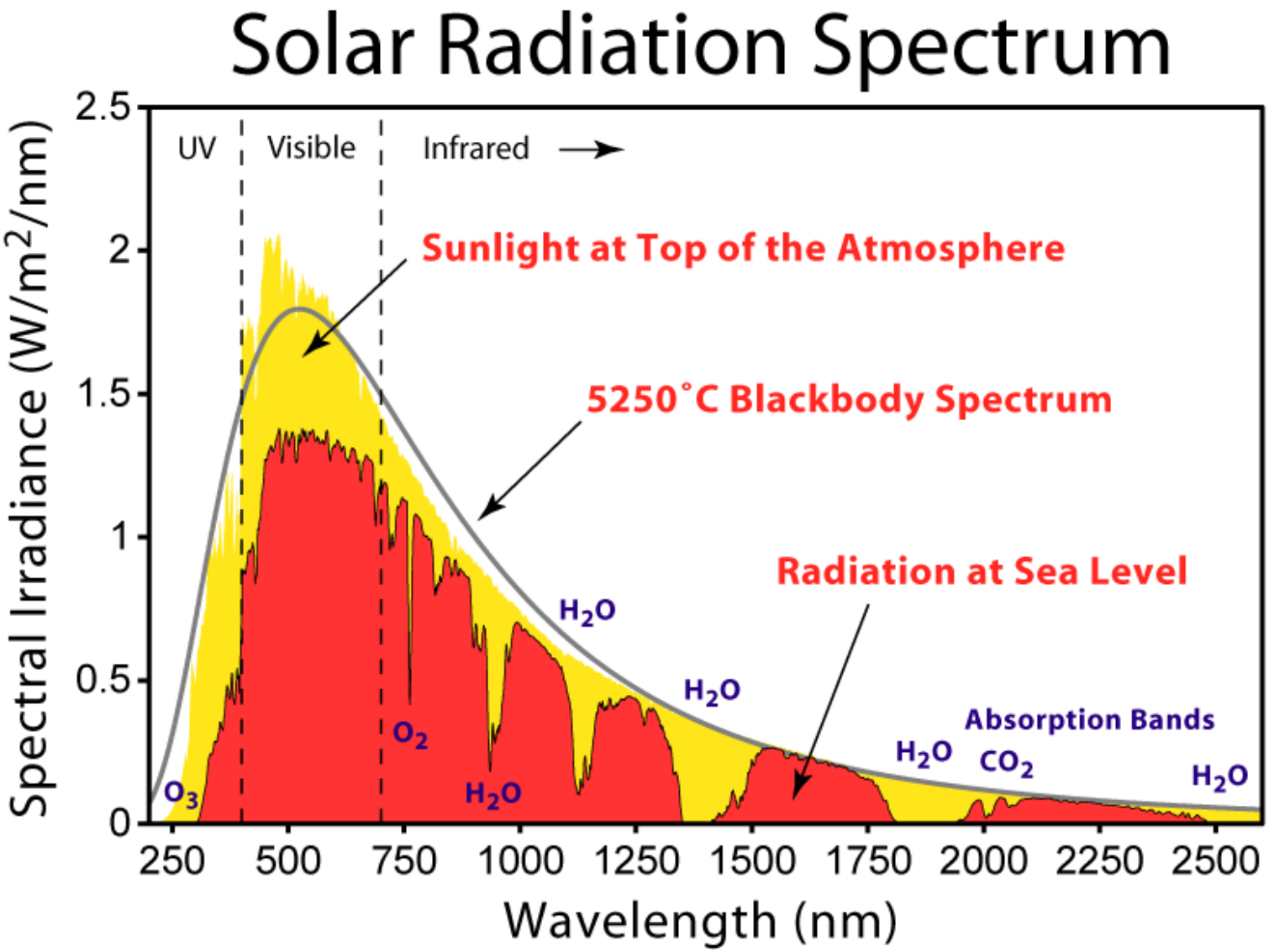
(Steffan - Boltzmann Constant)

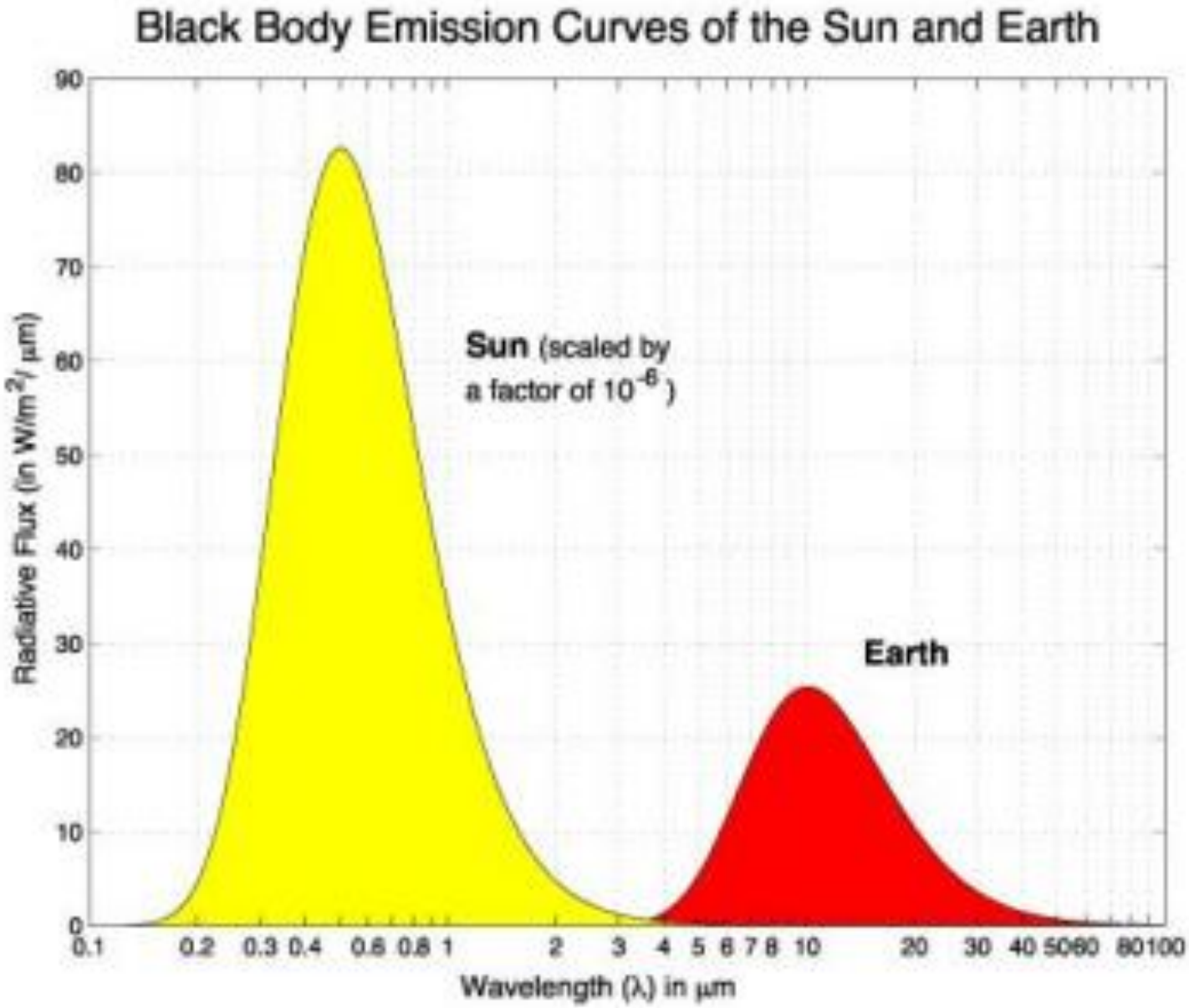
Wien Displacement Law:

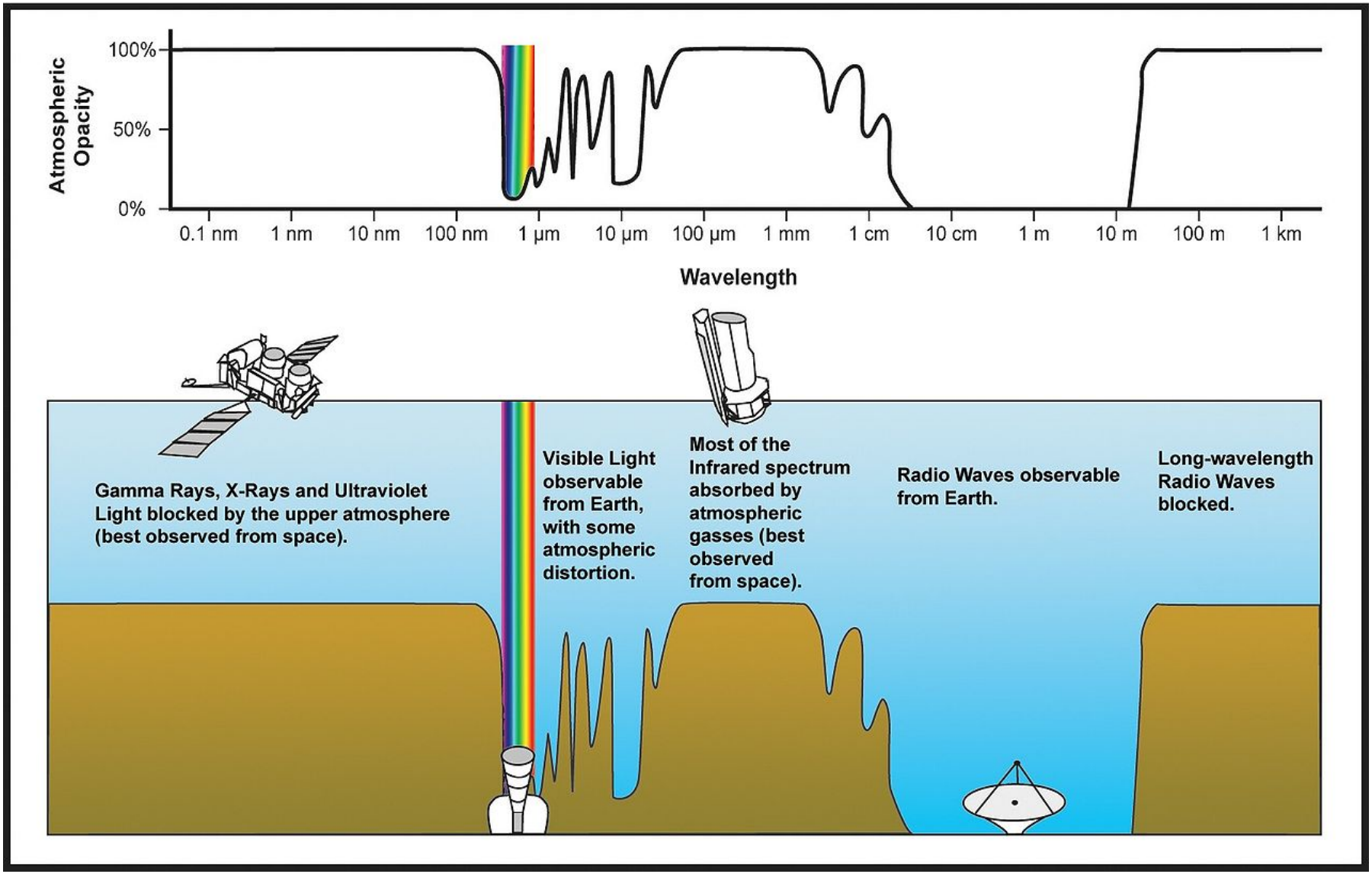
$$\lambda_{Max} = \frac{3 \times 10^7}{T}$$

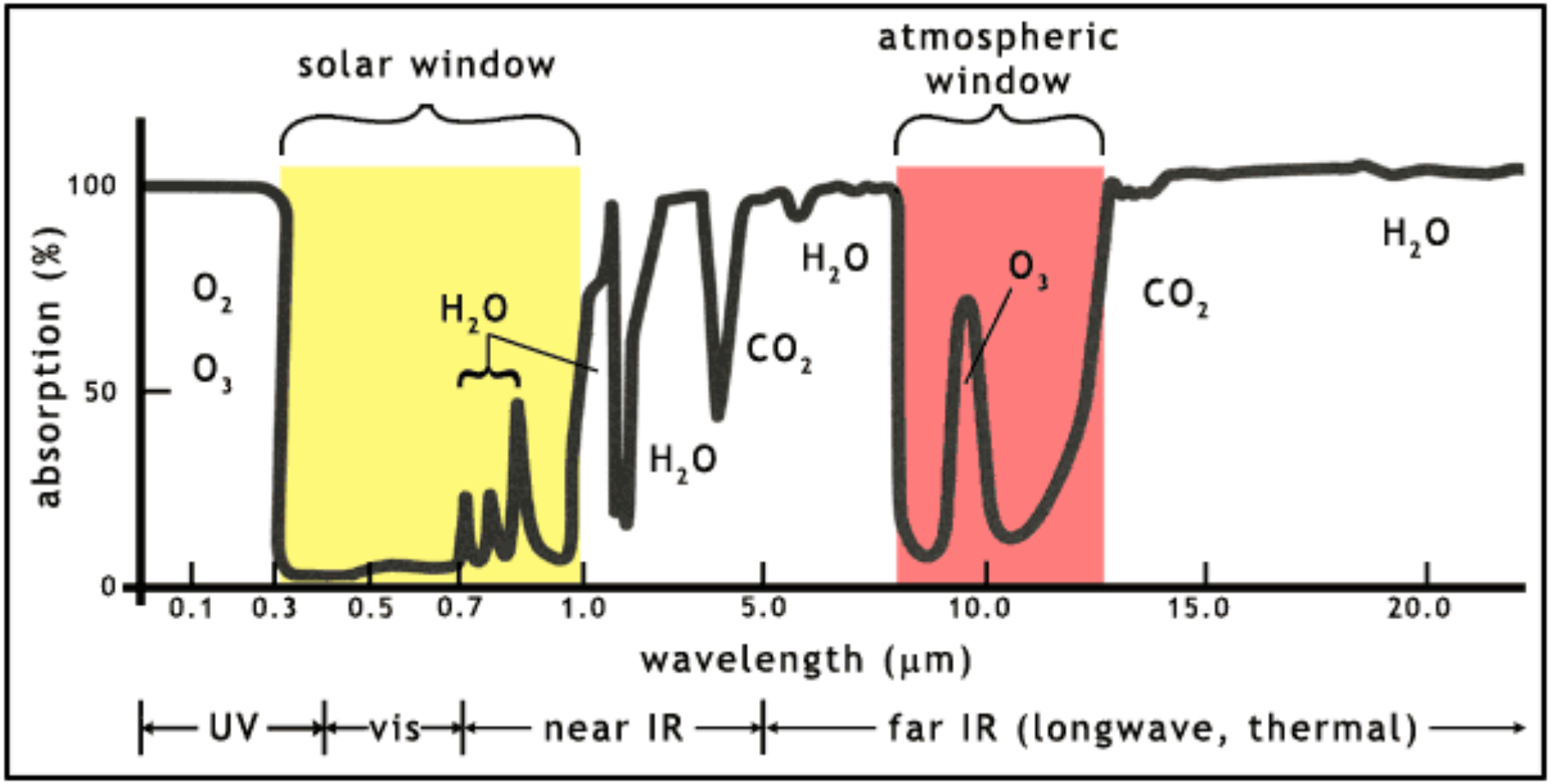
(λ in Angstroms T in Kelvin)

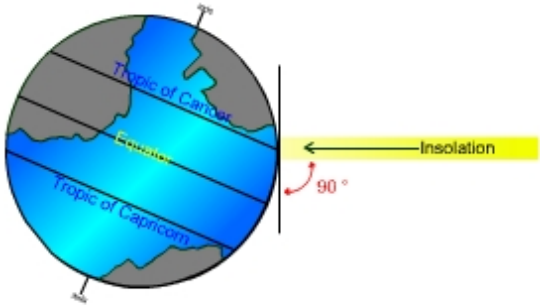

UV
VISIBLE
INFRARED
5000 K
4000 K
3000 K
Classical theory (5000 K)
Spectral radiance (kW · sr⁻¹ · m⁻² · nm⁻¹)
Wavelength (μm)
0
2
4
6
8
10
12
14
0
0.5
1
1.5
2
2.5
3


Solar Radiation Spectrum
Spectral Irradiance (W/m²/nm)
2.5
2
1.5
1
0.5
0
UV
Visible
Infrared
Sunlight at Top of the Atmosphere
5250˚C Blackbody Spectrum
Radiation at Sea Level
O3
O2
H2O
H2O
H2O
H2O
Absorption Bands
CO2
H2O
250
500
750
1000
1250
1500
1750
2000
2250
2500
Wavelength (nm)

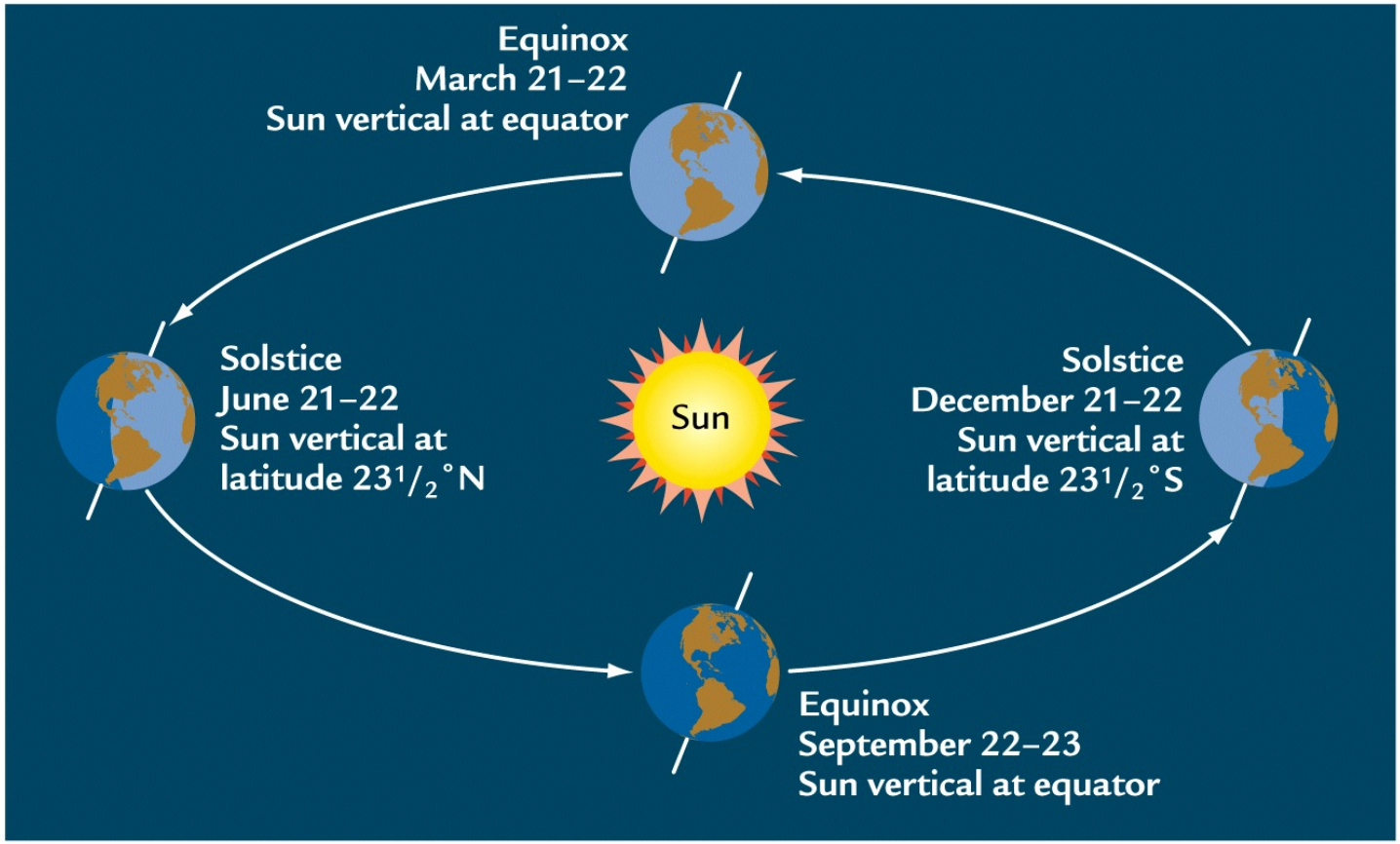

Black Body Emission Curves of the Sun and Earth
Radiative Flux (in W/m²/ μm)
Wavelength (λ) in μm
Sun (scaled by a factor of 10⁻⁶)
Earth
0
10
20
30
40
50
60
70
80
90
0.1
0.2
0.3
0.4
0.6
0.8
1
2
3
4
5
6
7
8
10
20
30
40
50
60
80
100


Atmospheric Opacity
100%
50%
0%
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength
Gamma Rays, X-Rays and Ultraviolet Light blocked by the upper atmosphere (best observed from space).
Visible Light observable from Earth, with some atmospheric distortion.
Most of the Infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio Waves observable from Earth.
Long-wavelength Radio Waves blocked.


solar window
atmospheric window
absorption (%)
100
50
0
O_2
O_3
H_2O
H_2O
CO_2
H_2O
O_3
CO_2
H_2O
0.1
0.3
0.5
0.7
1.0
5.0
10.0
15.0
20.0
wavelength (μm)
UV
vis
near IR
far IR (longwave, thermal)

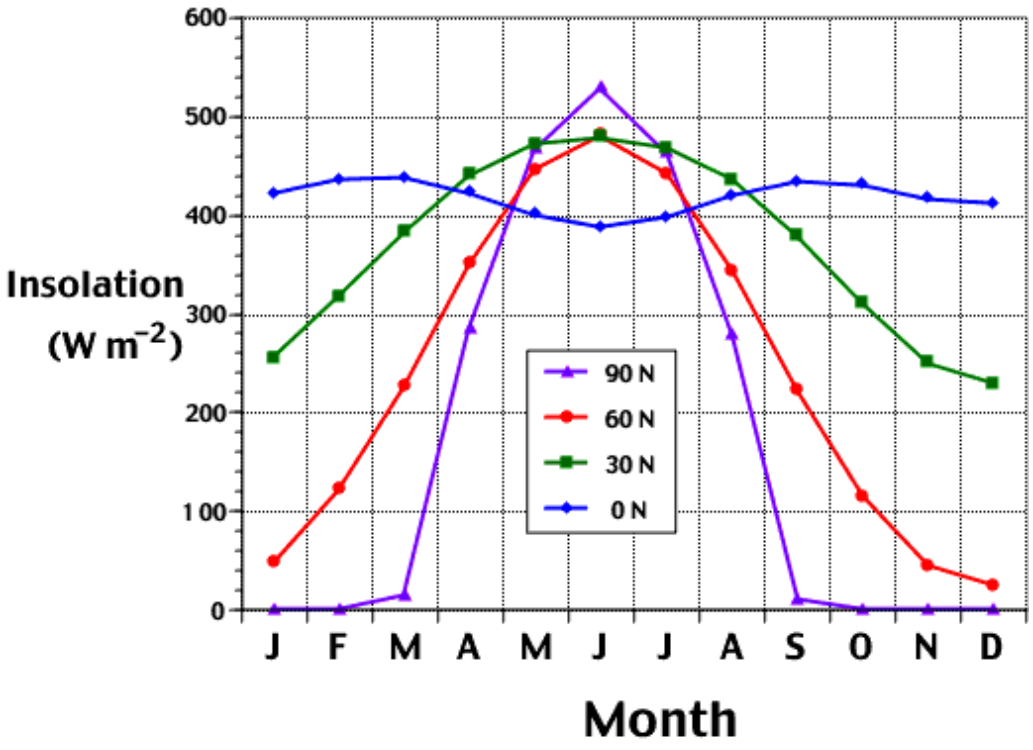


Earth

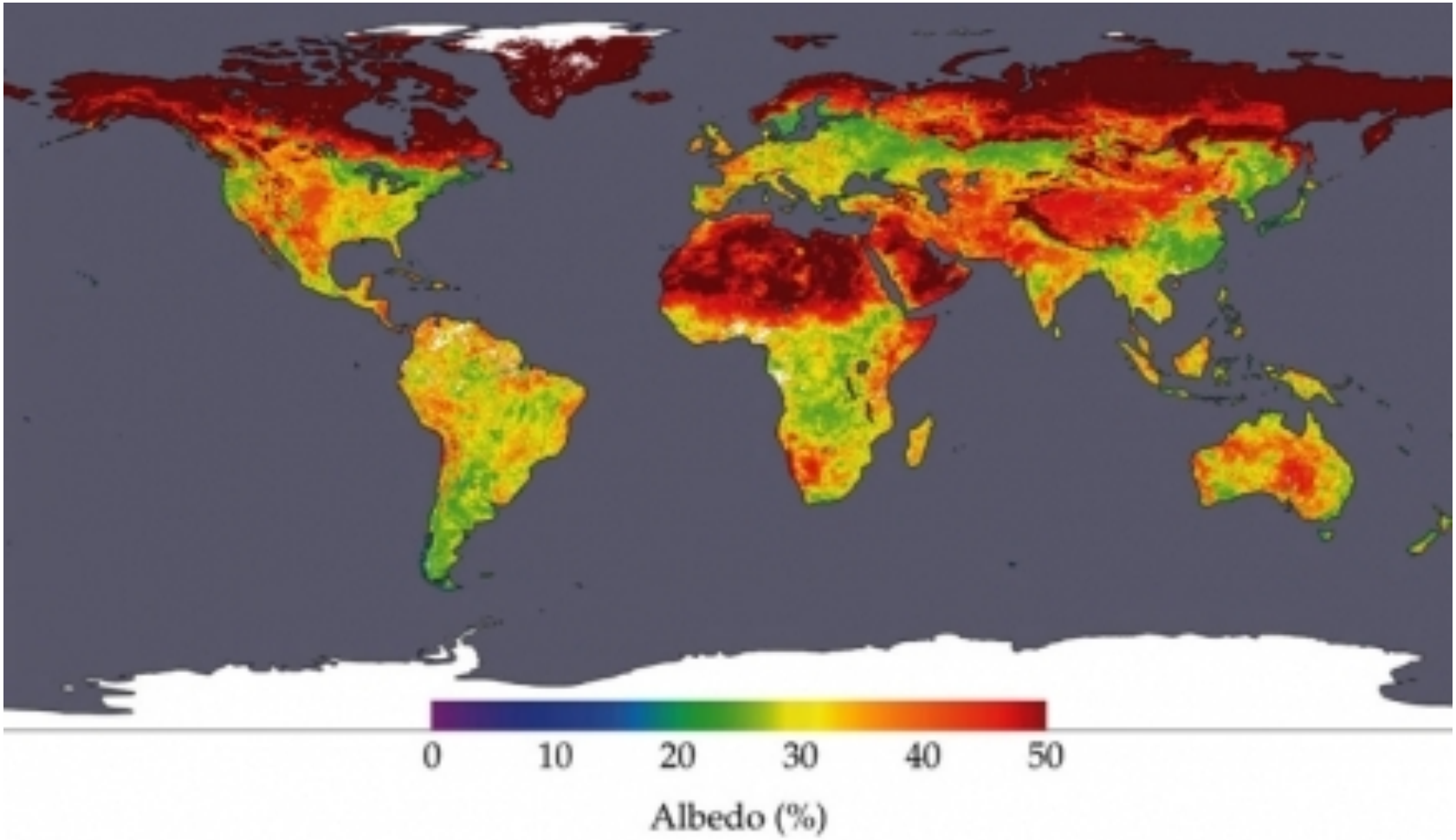


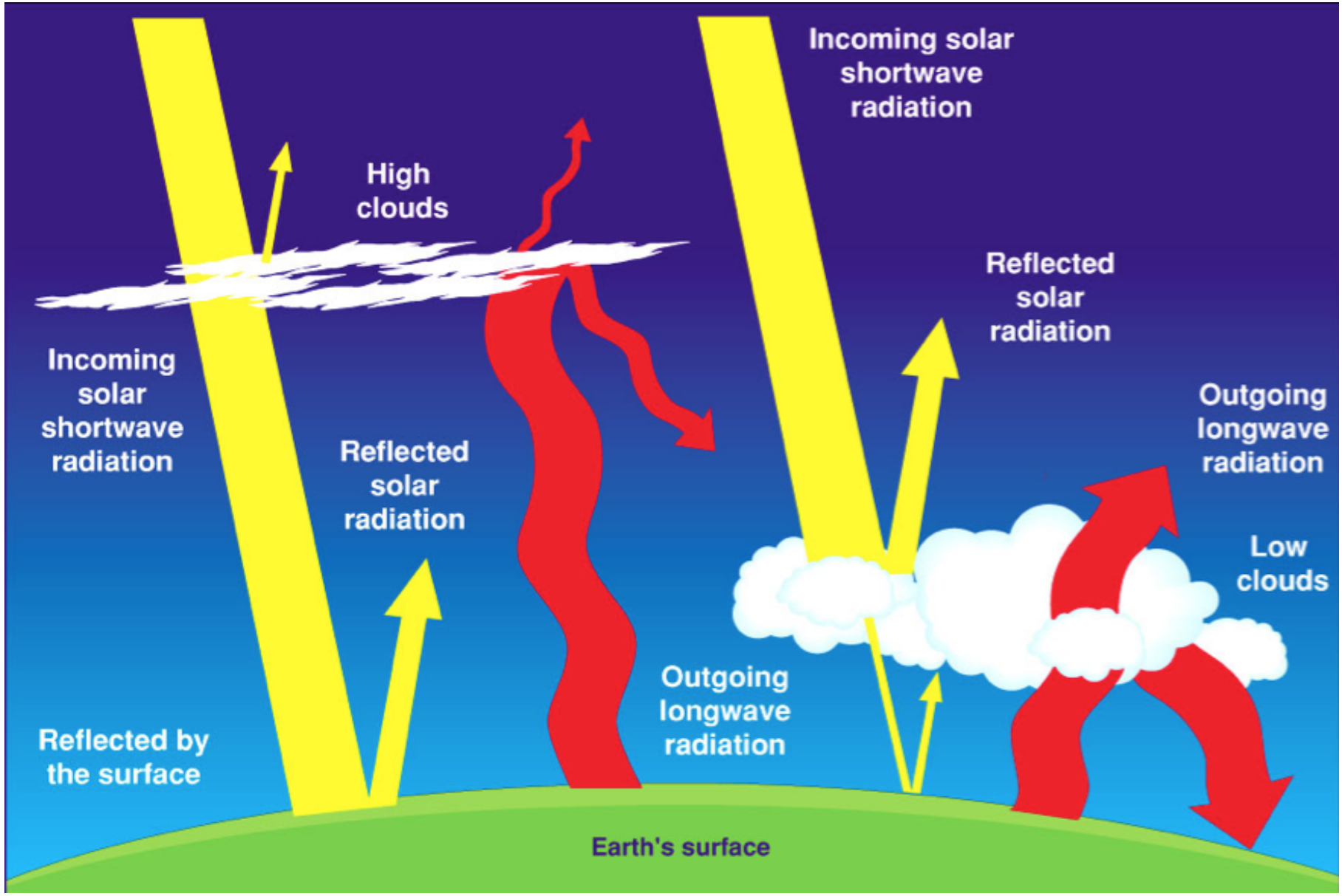
A

Earth's orbit

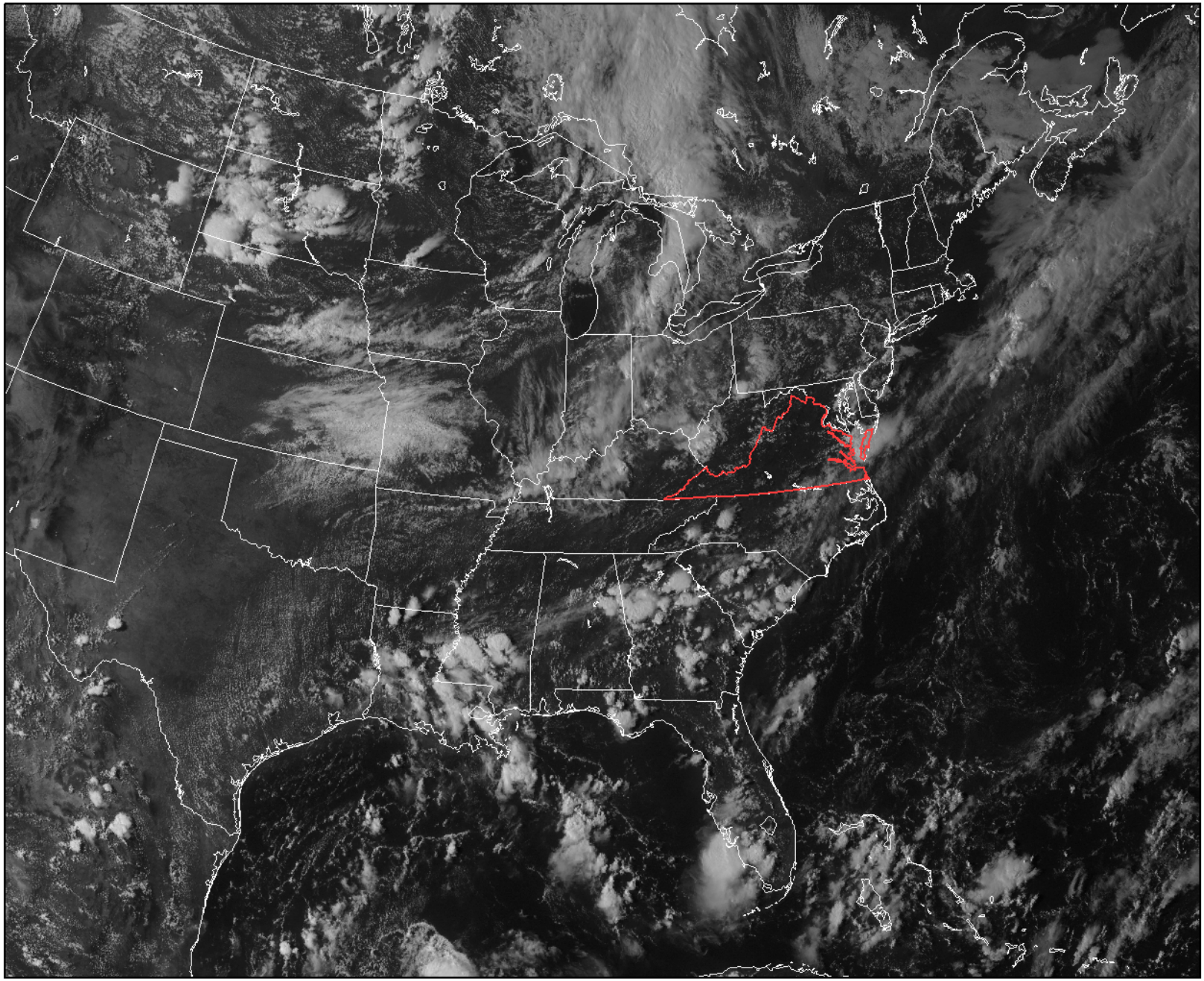

Insolation
(W m^{-2})
600
500
400
300
200
100
0
90 N
60 N
30 N
0 N
J F M A M J J A S O N D
Month

Surface albedo

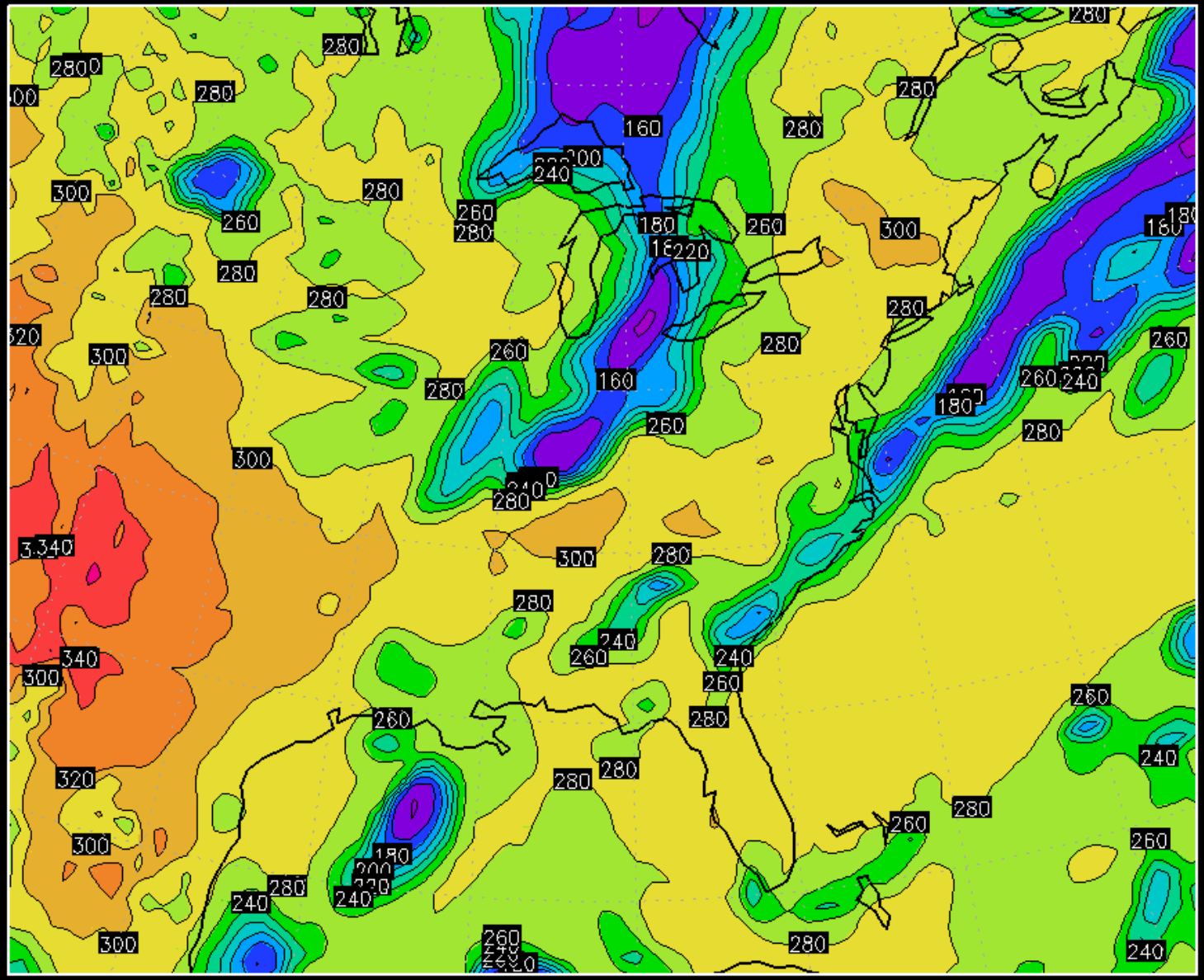



Incoming solar shortwave radiation
High clouds
Reflected solar radiation
Reflected by the surface
Incoming solar shortwave radiation
Reflected solar radiation
Outgoing longwave radiation
Low clouds
Outgoing longwave radiation
Earth's surface

21:15Z SEP 01, 2014 Contrast Enhanced Visible Satellite

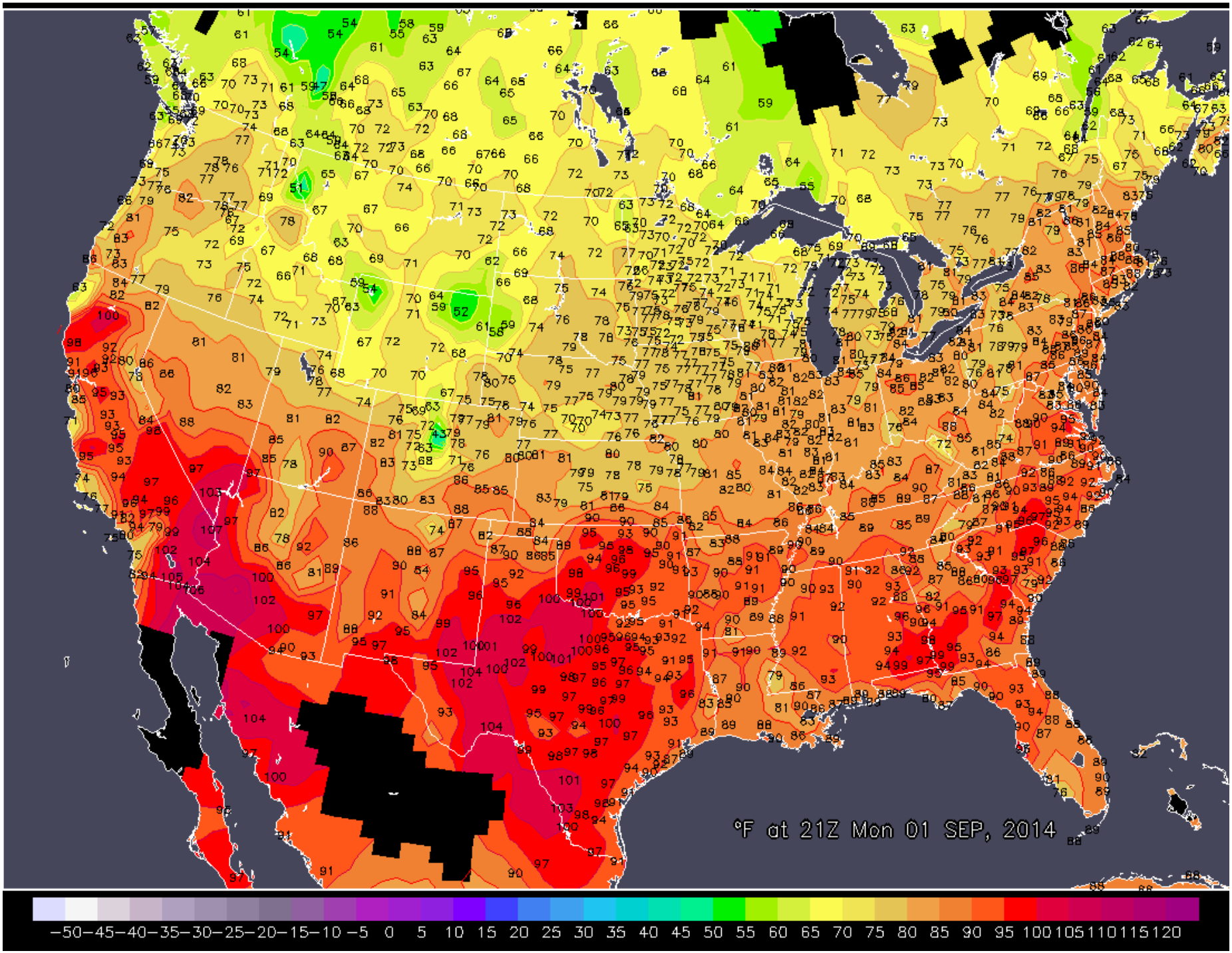


OLR 21Z 01 Sep 2014 (W/m²)

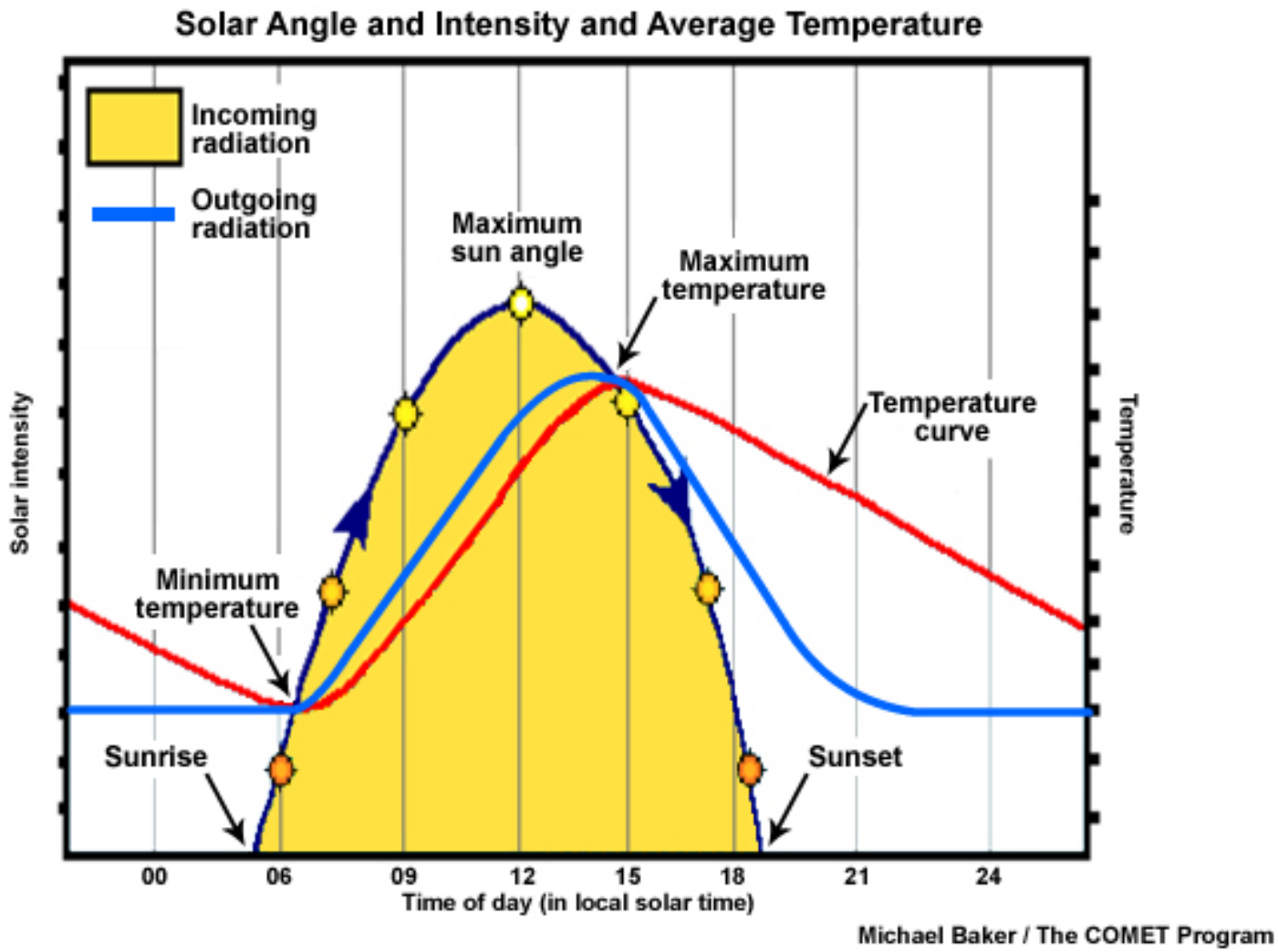


GrADS: COLA/IGES

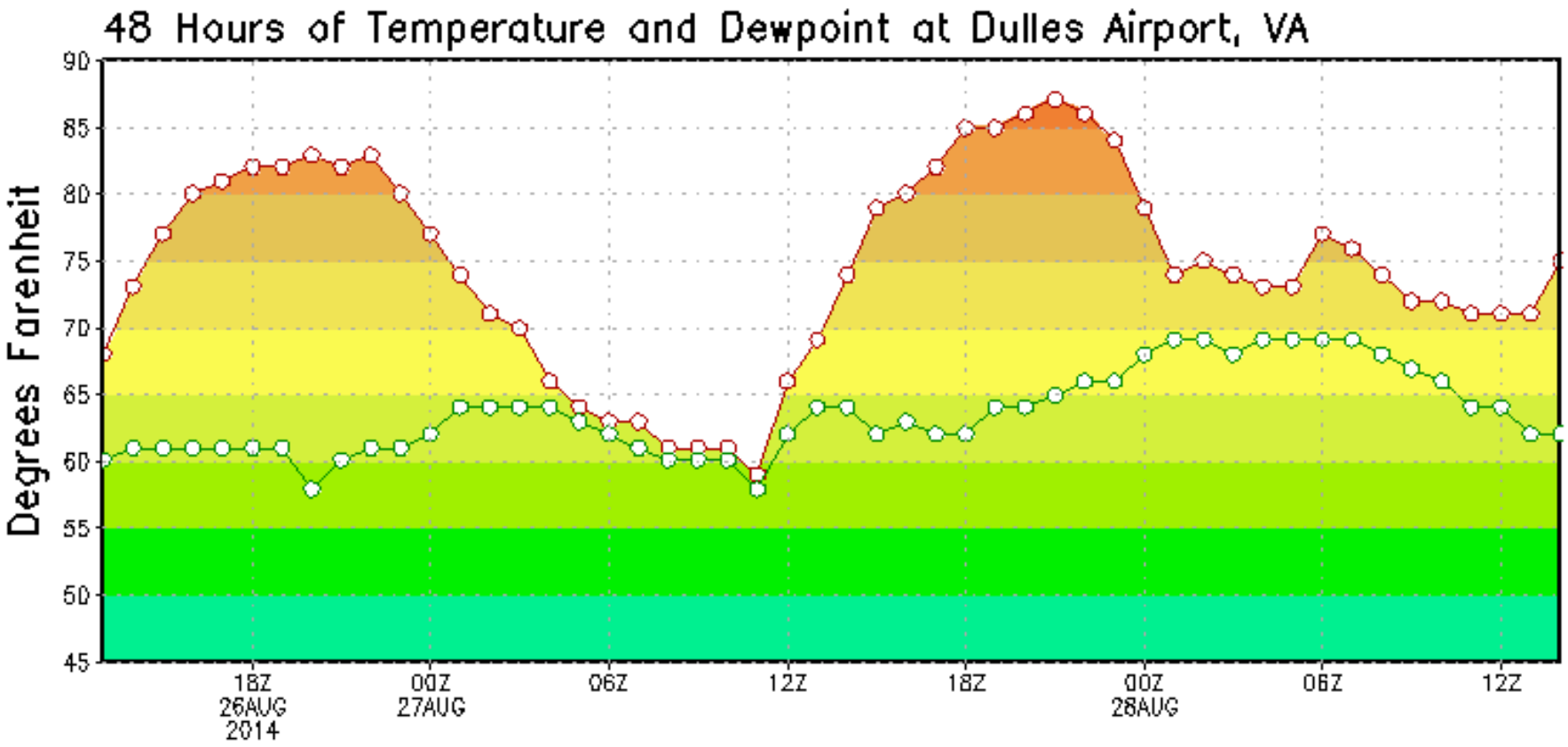
2014-09-01-18:20

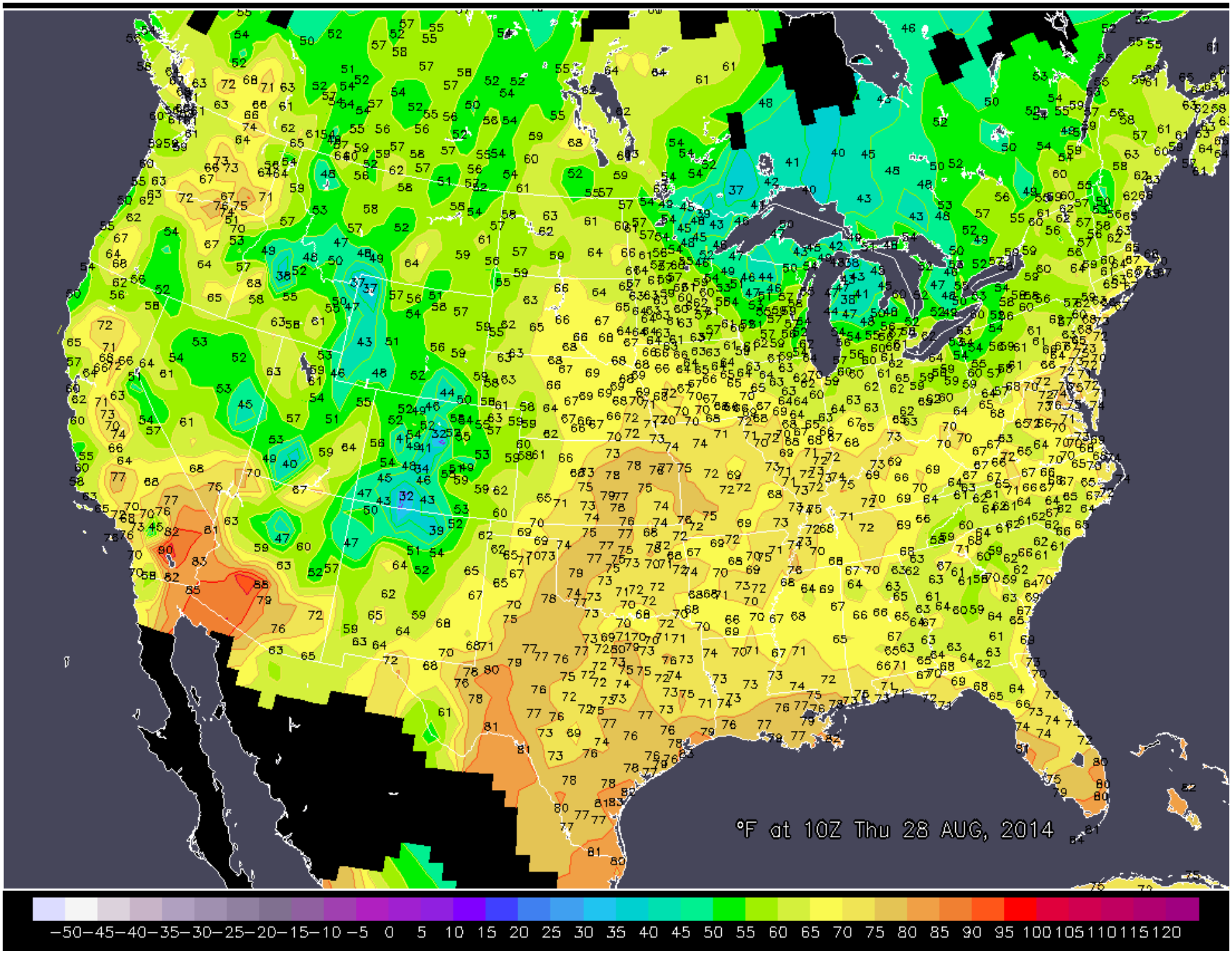

°F at 21Z Mon 01 SEP, 2014
−50 −45 −40 −35 −30 −25 −20 −15 −10 −5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120

Diurnal Temperature Variation



Why is there a delay in the maximum temperature w.r.t. maximum solar heating?


48 Hours of Temperature and Dewpoint at Dulles Airport, VA
Degrees Farenheit
90
85
80
75
70
65
60
55
50
45
18Z
26AUG
2014
00Z
27AUG
06Z
12Z
18Z
00Z
28AUG
06Z
12Z


°F at 10Z Thu 28 AUG, 2014
−50 −45 −40 −35 −30 −25 −20 −15 −10 −5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120