Set 1 for Cloudy Sky
First Approximation

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What is Set 1?

- Wielicki et al. (1996) (BAMS), Clouds and the Earth's Radiant Energy System (CERES):
  "Obtaining surface fluxes from measured TOA fluxes, CERES investigations are examining two independent approaches"
  Approach 1. Establishing direct relationships between TOA radiative fluxes and surface fluxes.
  Approach 2. Surface fluxes can be calculated by radiative transfer computations.

- CERES ATBD Algorithm Overview (Wielicki and Barkstrom, 1996):

- CERES will provide two types of surface fluxes: *first*, a set which attempts to directly relate CERES TOA fluxes to surface fluxes; *second*, a set which uses the best information on cloud, surface, and atmosphere properties to calculate surface, in-atmosphere, and TOA radiative fluxes, and then constrains the radiative model solution to agree with CERES TOA flux observations.

- *The first set*, using parametrization, is described in Subsystems 4.6.1–4.6.3 (1997):
  - Subsystem 4.6.1 is an empirical estimate of shortwave (SW) Surface Radiation Budget (SRB)
  - Subsystem 4.6.2 is an empirical estimate of longwave (LW) SRB
  - Subsystem 4.6.3 is an algorith for LW SRB total sky
- My Set 1 is a theoretical estimate of partitioning TSI into SW and LW, clear-sky, all sky and now, cloudy TOA and SFC RB in the annual global mean, based on an integer solution of four radiative transfer constraint equations; from which the first is well-known from Schwarzschild (1906), Goody (1964), Houghton (1977), Stephens (1992), etc.; the others are simple consequences.
- TOA SW are not there in the equations, they need another explanation; the method will be *geometrization*.

Four direct TOA/Surface relationships

CERES EBAF Ed4.1 Version 3, 22 years (April 2000 – March 2022) (Wm^{-2})

Eq. (1) **SFC** SW down – SW up + LW down – LW up (clear) = **TOA** LW (clear)/2

240.8680 – 29.0724 + 317.4049 – 398.5211 = 266.0122 /2 – 2.3267

Eq. (2) **SFC** SW down – SW up + LW down (clear) = 2 × **TOA** LW (clear)

240.8680 – 29.0724 + 317.4049 = 2 × 266.0122 – 2.8238

Eq. (3) **SFC** SW down – SW up + LW down – LW up (all) = [**TOA** LW (all) – LWCRE]/2

186.8544 – 23.1629 + 345.0108 – 398.7550 = (240.2450 – 25.7672)/2 + 2.7083

Eq. (4) **SFC** SW down – SW up + LW down (all) = 2 × **TOA** LW (all) + LWCRE

186.8544 – 23.1629 + 345.0108 = 2 × 240.2450 + 25.7672 + 2.4450

Mean **0.0007**

Four direct TOA/Surface relationships

CERES EBAF Ed4.1 Version 3, 22 years (April 2000 – March 2022) (Wm^{-2})

CERES EBAF Ed4.2.1 Version 3, 26 years (April 2000 – March 2026) (Wm^{-2})

Eq. (1) **SFC** SW down – SW up + LW down – LW up (clear) = **TOA** LW (clear)/2

240.8680 – 29.0724 + 317.4049 – 398.5211 = 266.0122 /2 – 2.3267

240.9690 – 29.6514 + 318.3627 – 399.0068 = 266.0064 /2 – 2.3297

Eq. (2) **SFC** SW down – SW up + LW down (clear) = 2 × **TOA** LW (clear)

240.8680 – 29.0724 + 317.4049 = 2 × 266.0122 – 2.8238

240.9690 – 29.6514 + 318.3627 = 2 × 266.0064 – 2.3325

Eq. (3) **SFC** SW down – SW up + LW down – LW up (all) = [**TOA** LW (all) – LWCRE]/2

186.8544 – 23.1629 + 345.0108 – 398.7550 = (240.2450 – 25.7672)/2 + 2.7083

187.1344 – 23.4117 + 346.4731 – 398.8196 = (240.4708 – 25.5356)/2 + 4.0017

Eq. (4) **SFC** SW down – SW up + LW down (all) = 2 × **TOA** LW (all) + LWCRE

186.8544 – 23.1629 + 345.0108 = 2 × 240.2450 + 25.7672 + 2.4450

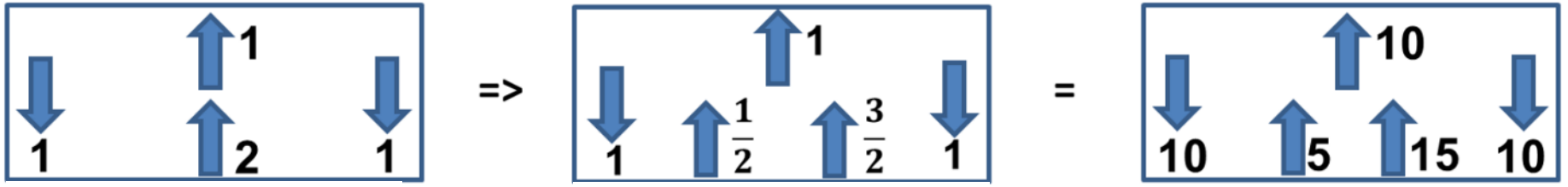
187.1344 – 23.4117 + 346.4731 = 2 × 240.4708 + 25.5356 + 3.8117

g(clear) = (398.5211 – 266.0122)/398.5211 = 0.33250 Mean **0.0007**

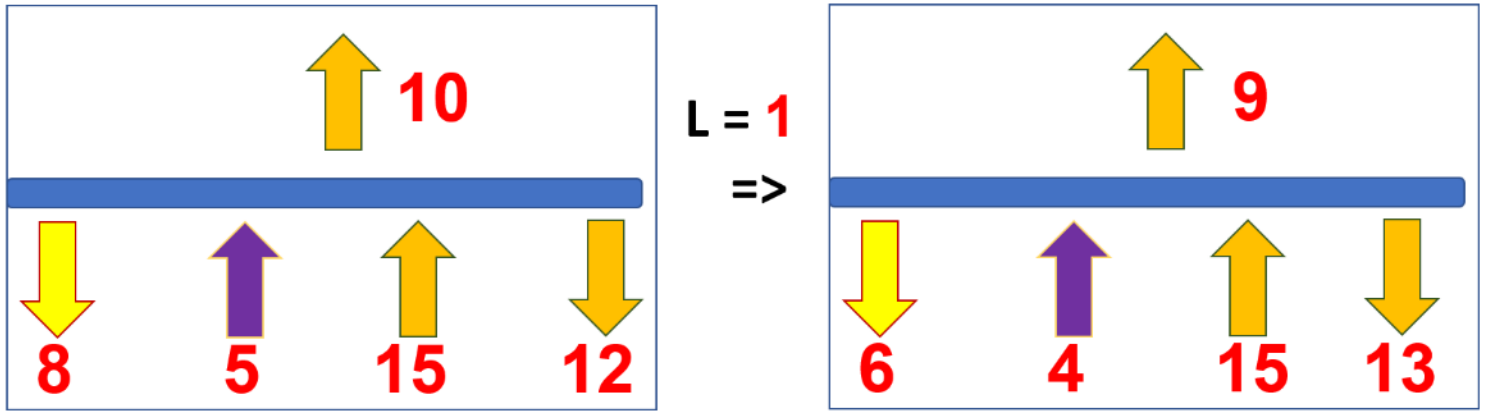
g(clear) = (399.0068 – 266.0064)/399.0068 = 0.33333 **0.7878**

The N-numbers as solution of the equations

Pure geometry **1 : 2 : 3 : 4** No reference to GHGs



Eq.(2) SFC Tot = 2OLR (Clear-sky) Eq.(1) SFC Net = OLR/2



$8 + 12 - 15 = 10 / 2$

$8 + 12 = 10 \times 2$

$6 + 13 - 15 = (9 - 1)/2$

$6 + 13 = 9 \times 2 + 1$

Eq. (1) SFC Net = OLR /2

Eq. (2) SFC Tot = 2OLR

Clear-sky

Eq. (3) SFC Net = (OLR – L)/2

Eq. (4) SFC Tot = 2OLR + L

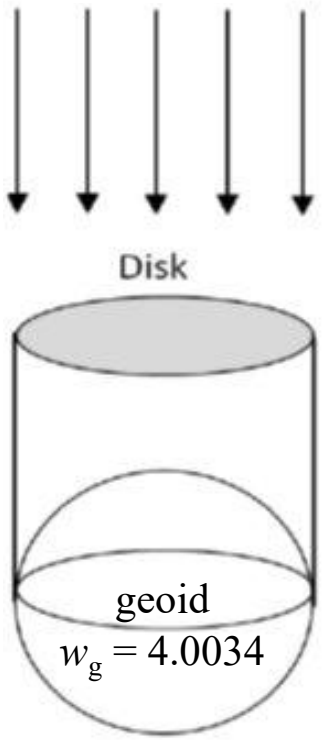
All-sky

Set 1 and Set 2 of CERES Data Products, Surface

The only input parameter

51

Solar flux



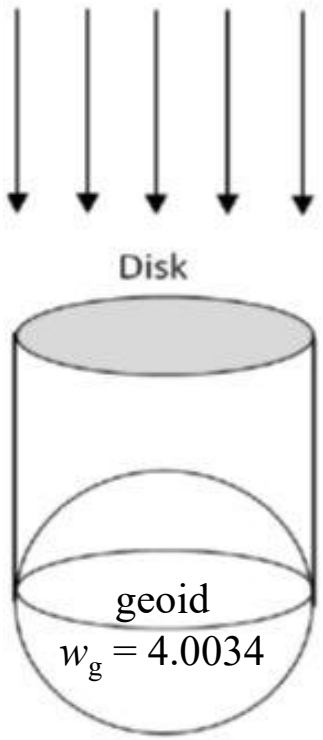
1 = 26.684 Wm^{-2}	**Set 1**		**Set 2**	**Difference**
Surface	**N**	**N** × Unit	EBAF Ed4.2.1 Aug 2000 – July 2026	**Set 2 – Set 1** **(Wm^{-2})**
Solar	**51**/4	**340.22**	**340.22**	**0.00**
SW net all	**6**	160.10	163.73	**3.63**
LW down all	**13**	346.84	346.62	**-0.22**
LW up all	**15**	400.20	398.88	**-1.32**
LW net all	**-2**	-53.37	-52.26	**1.11**
SW net clear	**8**	213.46	211.32	**-2.14**
LW down clear	**12**	320.20	318.44	**-1.76**
LW up clear	**15**	400.25	399.07	**-1.18**
LW net clear	**-3**	-80.05	-80.63	**-0.58**

Set 1 and Set 2 of CERES Data Products, TOA

The only input parameter

51

Solar flux



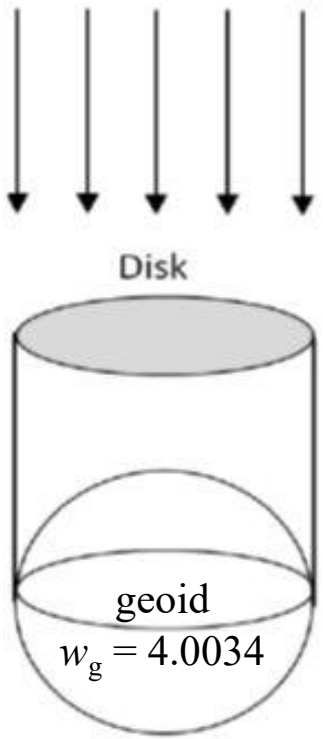
1 = 26.684 Wm^{-2}	**Set 1**		**Set 2**	**Difference**
TOA	**N**	**N** × Unit	EBAF Ed4.2.1 Aug 2000 – July 2026	**Set 2 – Set 1** **(Wm^{-2})**
Solar	**51**/4	**340.22**	**340.22**	**0.00**
SW up all	**15**/4	100.06	98.82	**-1.24**
LW up all	**36**/4	240.15	240.49	**0.34**
Net all	**0**	0	0.92	**0.92**
SW up clear	**8**/4	53.37	53.73	**0.36**
LW up clear	**40**/4	266.84	266.00	**-0.84**
Net clear	**3**/4	20.01	20.49	**0.48**
SW CRE	**–7**/4	-46.70	-45.11	**1.59**
LW CRE	**4**/4	26.684	25.52	**-1.16**
Net CRE	**–3**/4	-20.01	-19.58	**0.43**

TOA SW are not in the eqs — need explanation

The only input parameter

51

Solar flux



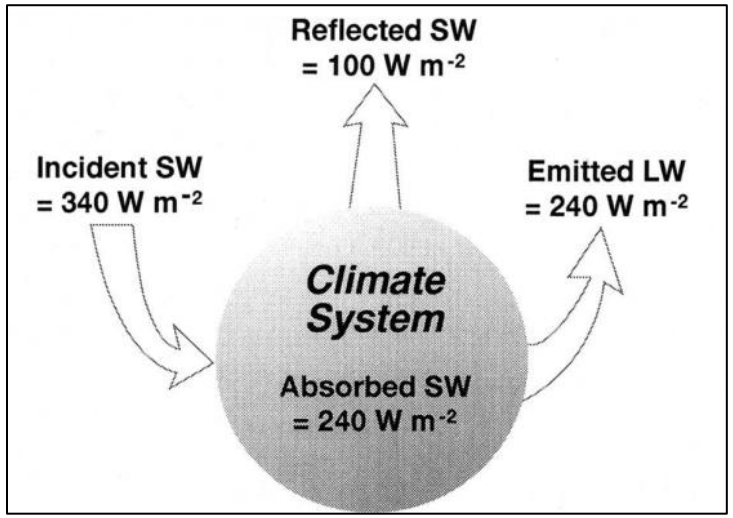
1 = 26.684 Wm^{-2}	**Set 1**		**Set 2**	**Difference**
TOA	**N**	**N** × Unit	EBAF Ed4.2.1 Aug 2000 – July 2026	**Set 2 – Set 1 (Wm^{-2})**
Solar	**51**/4	**340.22**	**340.22**	**0.00**
SW up all	**15**/4	100.06	98.82	**-1.24**
LW up all	**36**/4	240.15	240.49	**0.34**
Net all	**0**	0	0.92	**0.92**
SW up clear	**8**/4	53.37	53.73	**0.36**
LW up clear	**40**/4	266.84	266.00	**-0.84**
Net clear	**3**/4	20.01	20.49	**0.48**
SW CRE	**–7**/4	-46.70	-45.11	**1.59**
LW CRE	**4**/4	26.684	25.52	**-1.16**
Net CRE	**–3**/4	-20.01	-19.58	**0.43**

TOA all-sky was exact already in Wielicki et al. (1995)

α(Theory) = **15**/**51**
α(Wielicki) = 100/340 ≡ 15/51

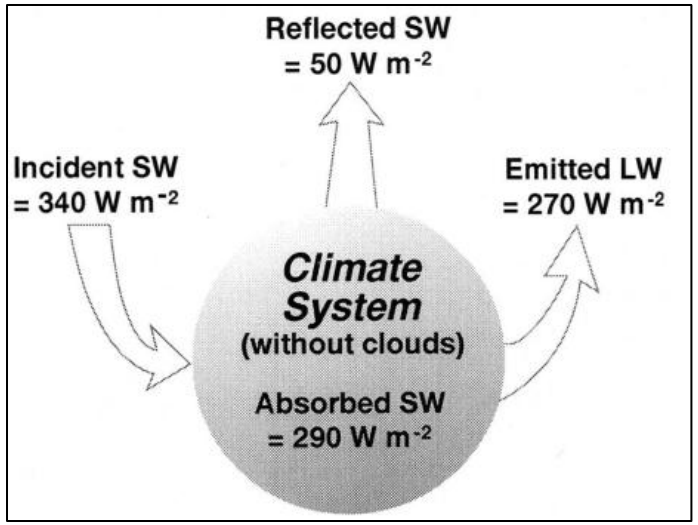
Mission to Planet Earth:
Role of Clouds and
Radiation in Climate

Bruce A. Wielicki,*
Robert D. Cess,+
Michael D. King,#
David A. Randall,@
and Edwin F. Harrison*



All-sky

Incident SW = 340 Wm^{-2} = **51**/4
Reflected SW = 100 Wm^{-2} = **15**/4
Absorbed SW = 240 Wm^{-2} = **36**/4
Emitted LW = 240 Wm^{-2} = **36**/4



Clear-sky

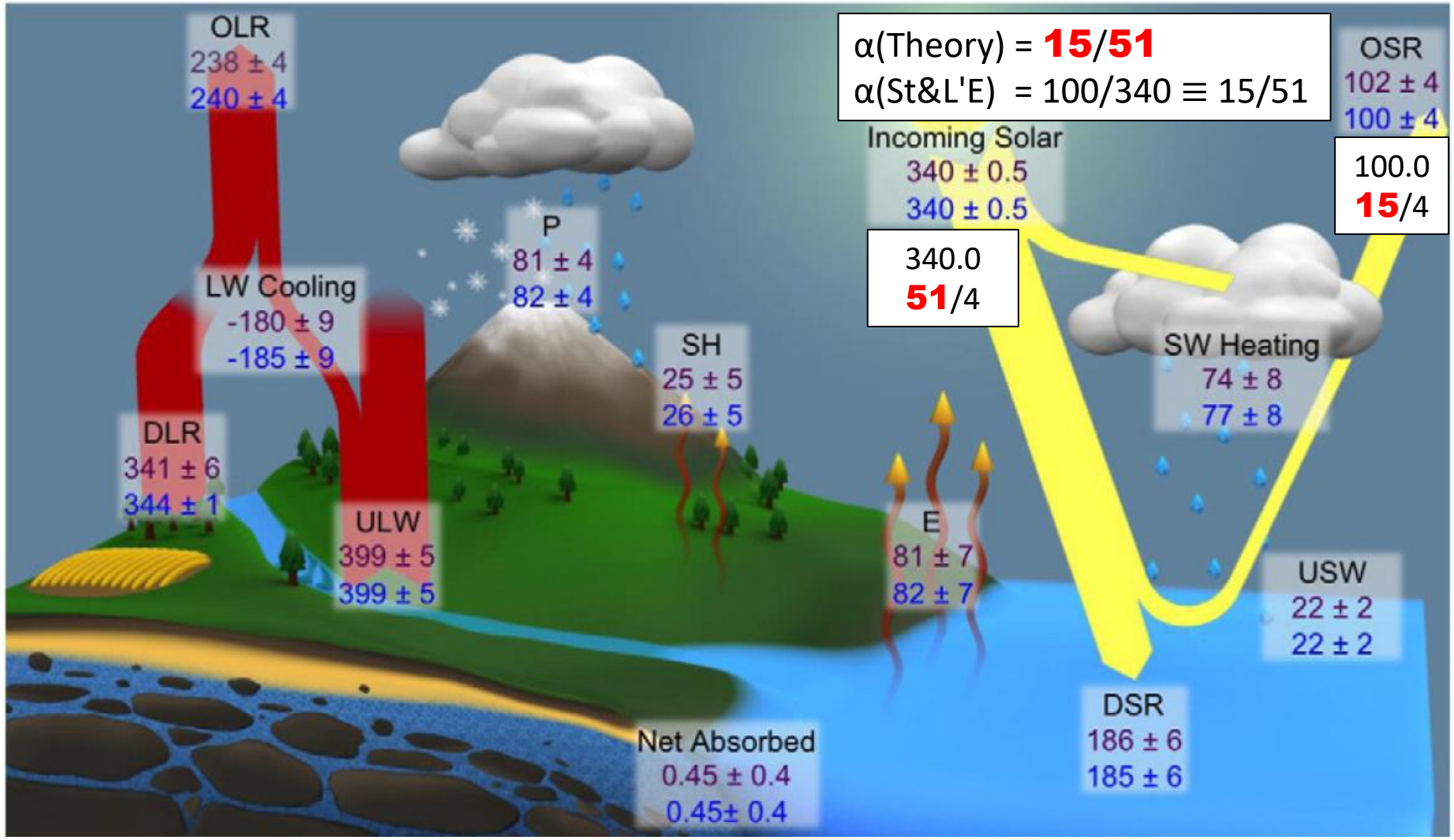
Incident SW = 340 Wm^{-2} = **51**/4
Reflected SW = 53.33 Wm^{-2} = **8**/4
Absorbed SW = 286.67 Wm^{-2} = **43**/4
Emitted LW = 266.66 Wm^{-2} = **40**/4

LW CRF = 26.68 Wm^{-2} = **4**/4
SW CRF = -46.69 Wm^{-2} = -**7**/4
NET CRF = -20.01 Wm^{-2} = -**3**/4
TOA Net Clear = 20.01 Wm^{-2} = **3**/4

Cloud-Radiative Forcing (CRF)
LW CRF = 30 W m^{-2}
SW CRF = -50 W m^{-2}
NET CRF = -20 W m^{-2}

Same as in Stephens & L'Ecuyer (2015)

G.L. Stephens, T. L'Ecuyer / Atmospheric Research 166 (2015) 195–203



Same as in AMS Monograph (2018)

Chapter 4

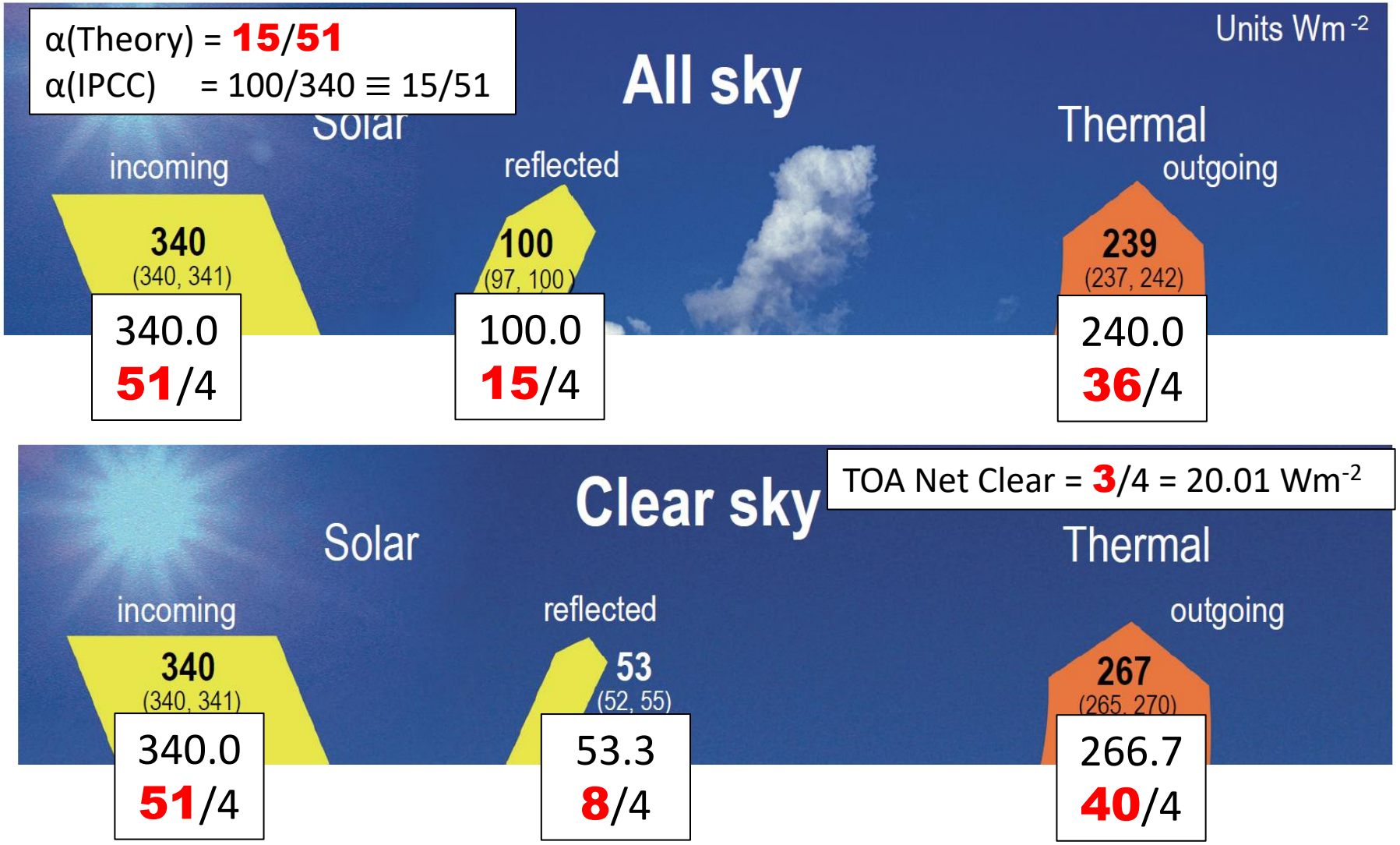
Satellites See the World's Atmosphere

S. A. ACKERMAN,[a,b] S. PLATNICK,[c] P. K. BHARTIA,[c] B. DUNCAN,[d] T. L'ECUYER,[a,b] A. HEIDINGER,[e] G. SKOFRONICK-JACKSON,[f] N. LOEB,[g] T. SCHMIT,[e] AND N. SMITH[h]

however, early estimates of the planetary energy balance have stood the test of time. The CERES flying on the *Terra* and *Aqua* satellites confirm that Earth's albedo is 29.4% (±0.3%) and that the planet emits at an equivalent blackbody temperature of 255 K (±1 K; Wielicki et al. 1996; L'Ecuyer et al. 2015).

$0.294 = 100/340 \equiv$ **15/51**

Same as in Wild (2020) / IPCC (2023)

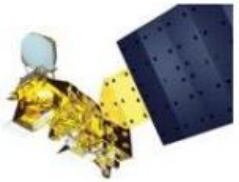


CERES_EBAF_Ed4.2.1_Subset_200008-202607.nc

301	332,0385	90,9395	48,83918	244,8376	269,5647	13,63479	-17,3733
302	336,6115	92,3574	49,57737	243,8965	268,4265	18,60764	-18,2501
303	342,4201	98,5185	52,61893	241,6214	266,4104	23,3906	-21,1104
304	347,9292	103,8936	56,21173	239,3803	264,207	27,51007	-22,8548
305	351,2633	106,0121	56,64134	237,2423	262,8878	31,73367	-23,7249
306	351,5424	103,497	55,35809	238,2617	263,0665	33,11744	-23,3339
307	348,7133	99,3123	54,08836	238,9895	263,744	30,88075	-20,4693
308	343,7661	96,9726	53,05853	239,2176	264,2255	26,48198	-18,9061
309	337,9482	95,2425	54,37961	239,367	264,7003	18,86855	-15,5298
310	333,0062	96,5602	54,63071	241,5731	267,08	11,29585	-16,4228
311	329,9815	94,5381	51,54137	243,7297	268,8969	9,543582	-17,8297
312	329,5762	91,7751	49,79973	246,1218	270,5398	9,236981	-17,5576
313	solar	toa_sw_all	toa_sw_cl	lw_all	toa_lw_cl	toa_net_cl	toa_cre_net
314	**340,22**	**98,82**	**53,73**	**240,49**	**266,00**	**20,49**	**-19,58**
315	**51**/4	**15**/4	**8**/4	**36**/4	**40**/4	**3**/4	**–3**/4
316	340.22	100.05	53.37	240.16	266.84	20.01	–20.01

Libera will tell us how much they really are

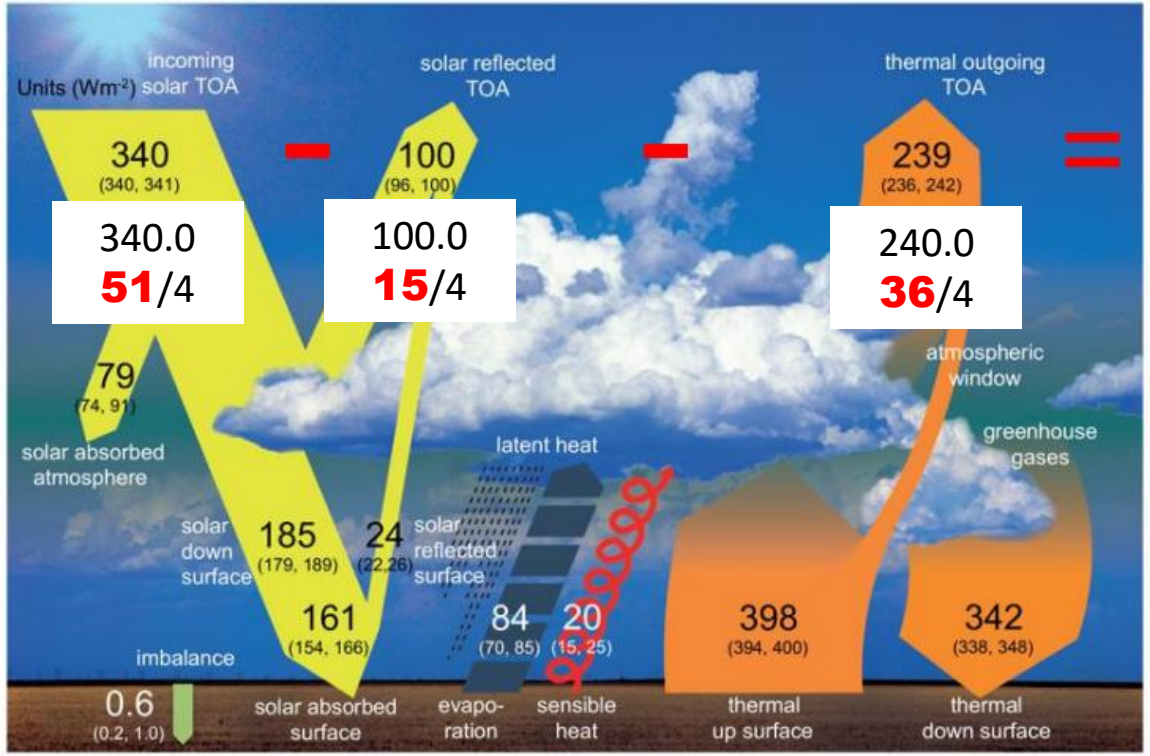
Top-of-the-atmosphere Radiation and Earth's (Radiative) Energy Imbalance (EEI)



CERES & future Libera
Clouds and Earth's Radiant Energy System

SORCE & TSIS
Solar Radiation and Climate Experiment
Total and Spectral *Solar* Irradiance Sensor

Processing heavily involves Imager (VIIRS) and Geo data



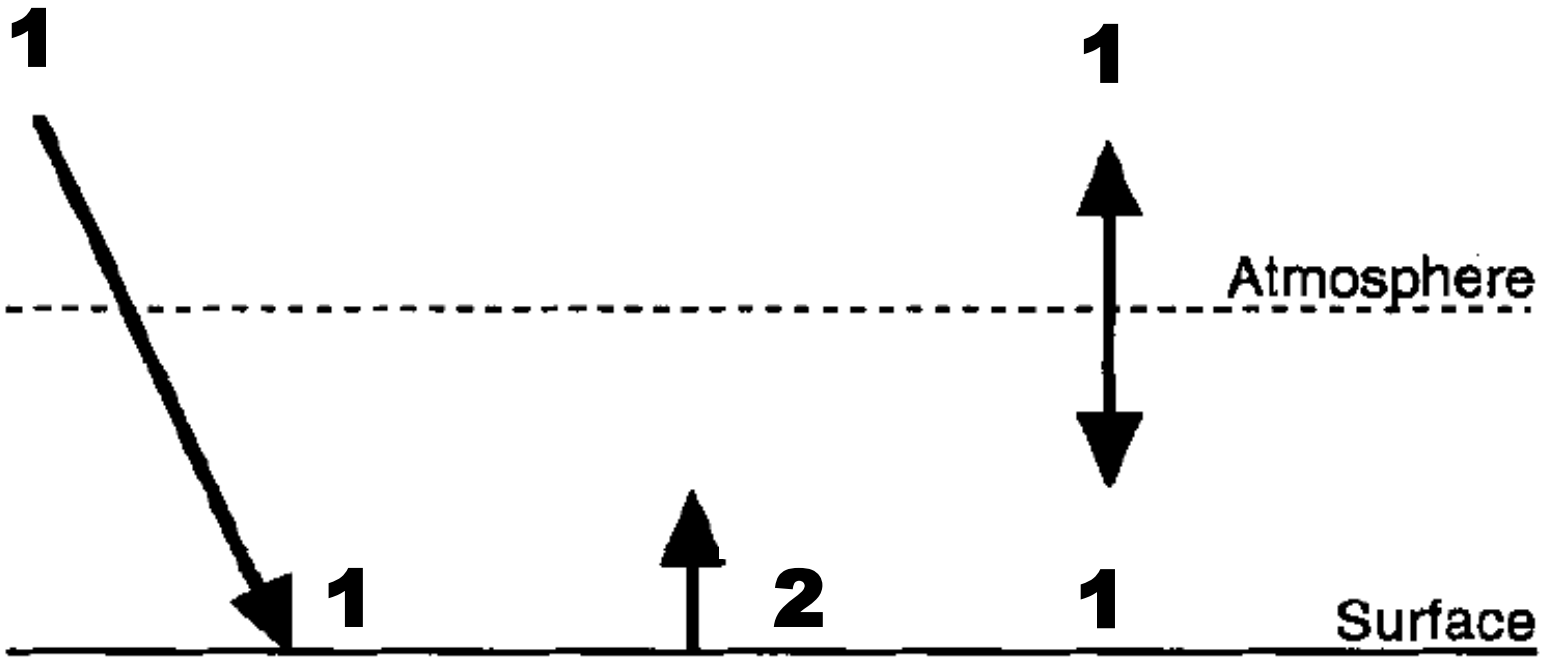
~1 Wm^{-2}

Updated from IPCC AR5 / Wild et al. 2013, 2015 Climate Dynamics

Hakuba (2024)

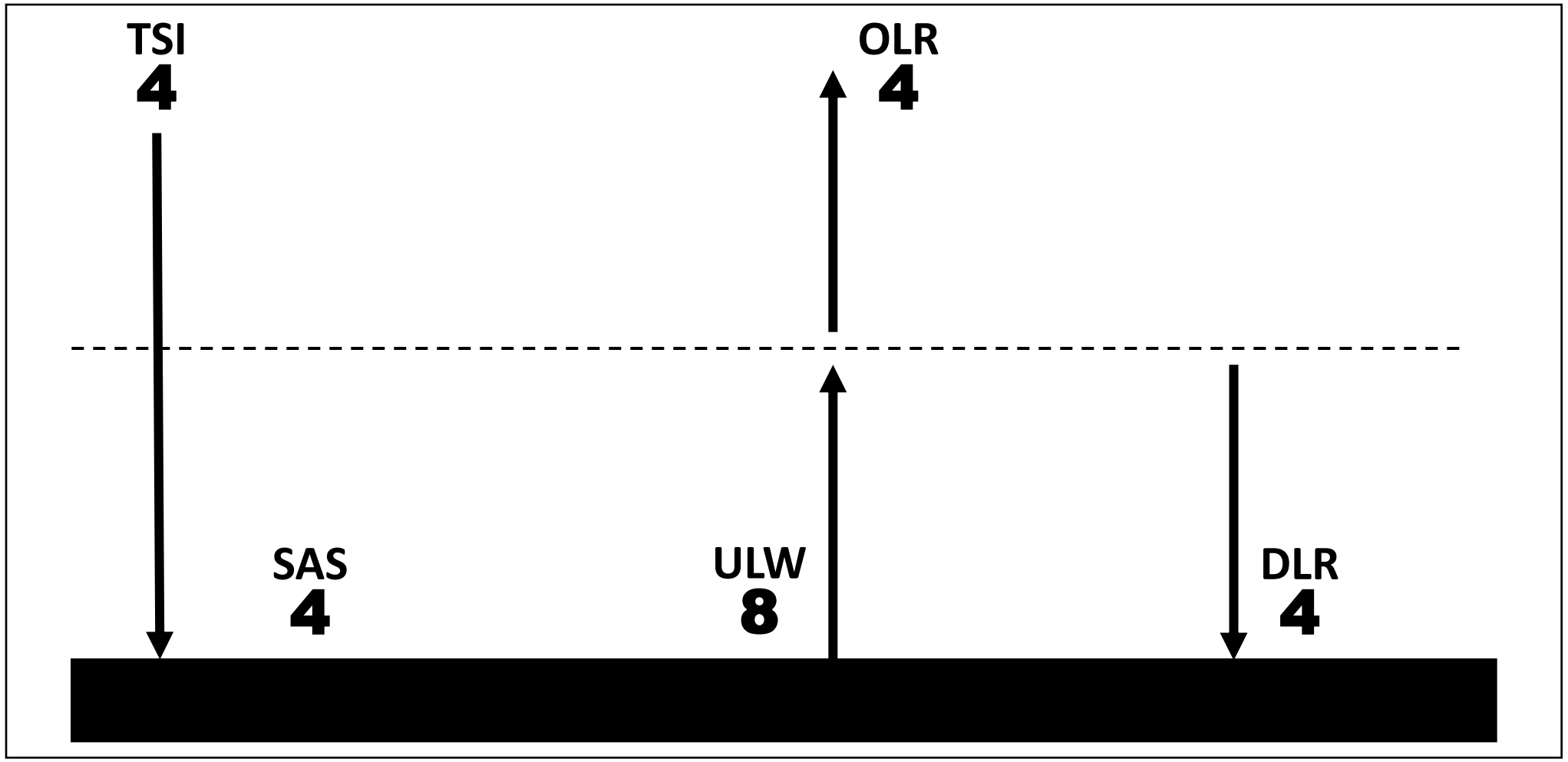
A geometric greenhouse model

Starting from the simplest radiative structure

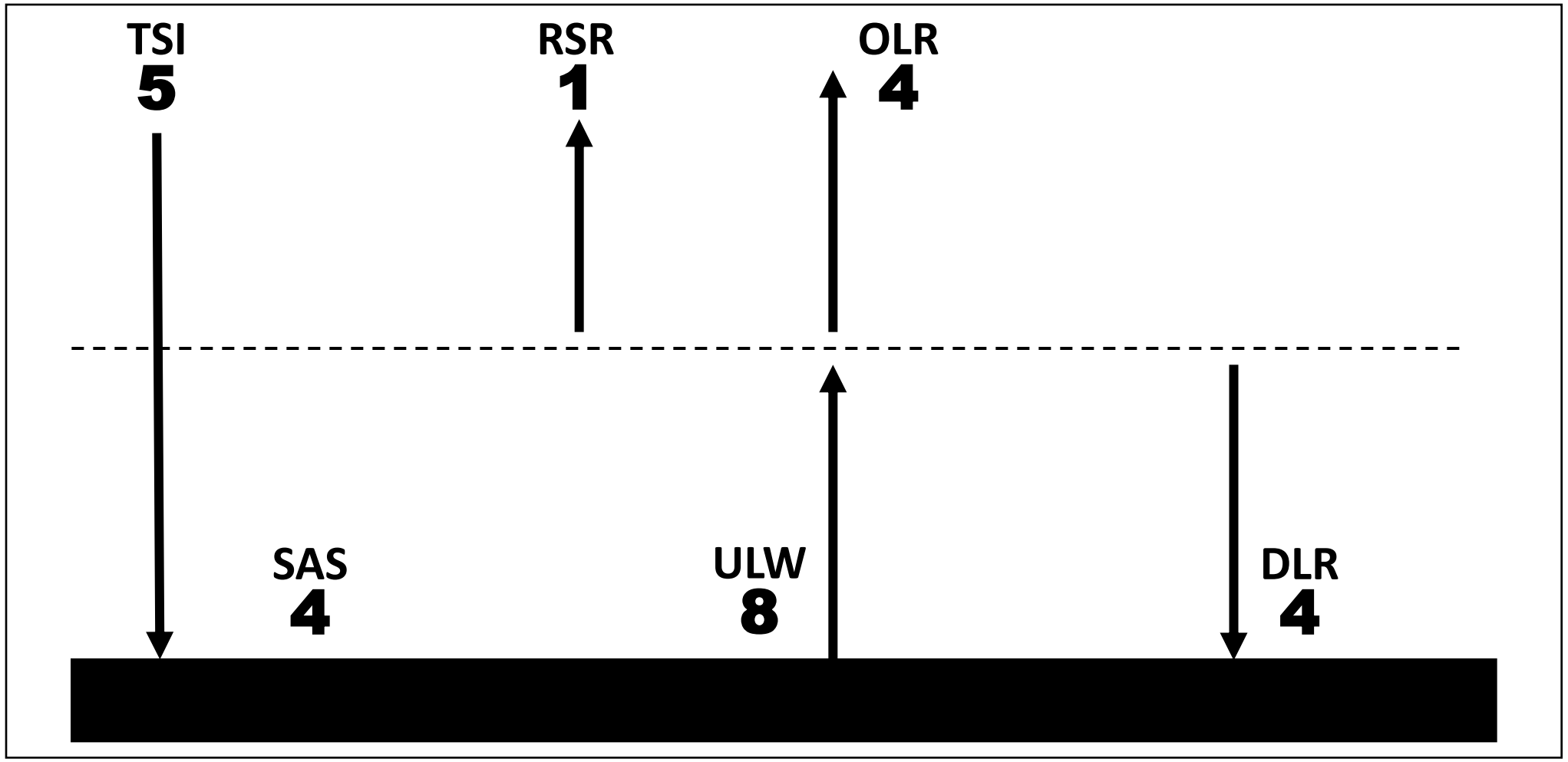


Hartmann (1994), Fig. 2.3

Multiply by 4

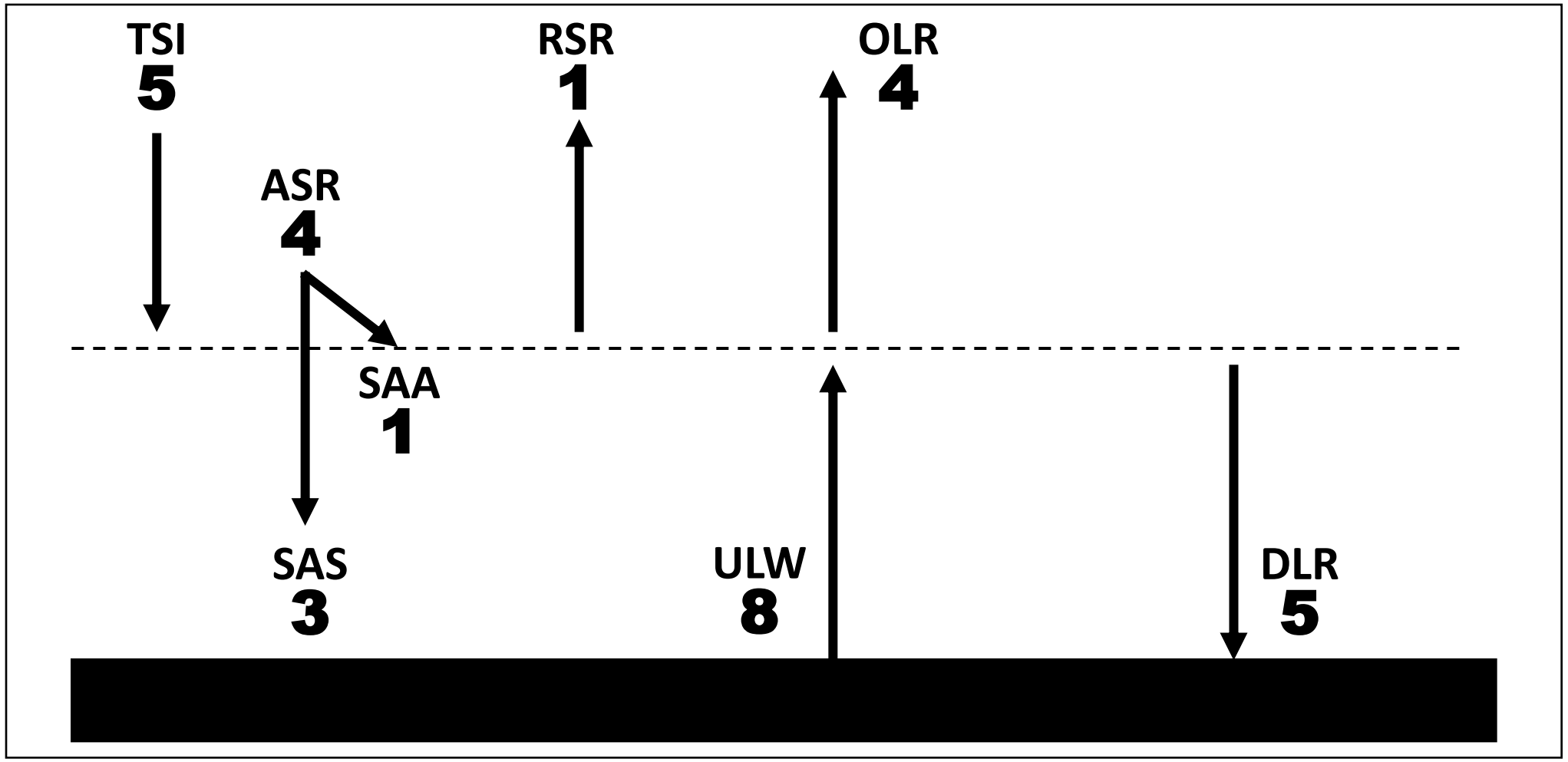


Introduce 1 unit RSR, add 1 to TSI



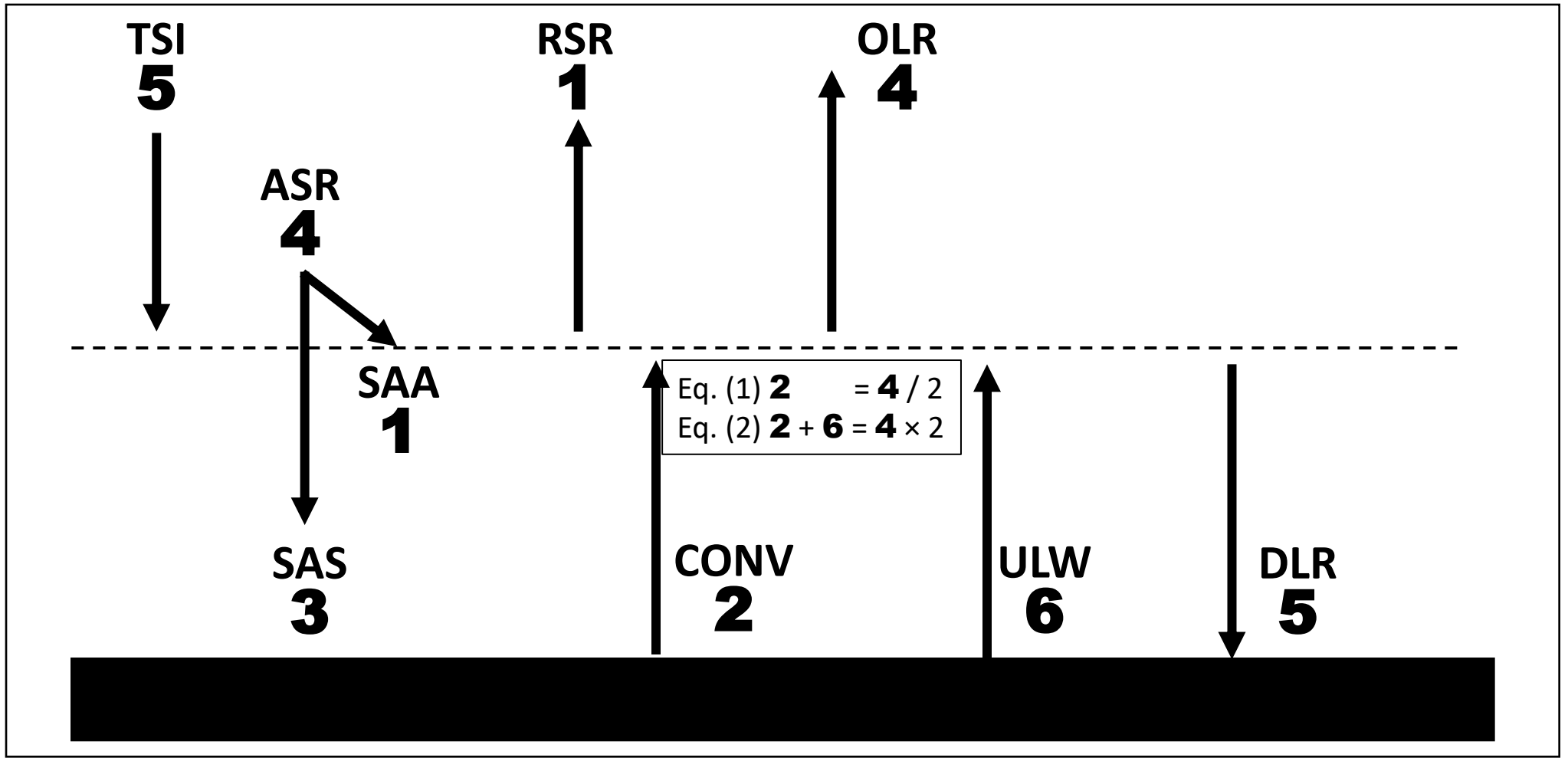
No reference to any surface or atmospheric reflectivity

Allow **1** unit SAA (Solar Absorbed Atmosphere)



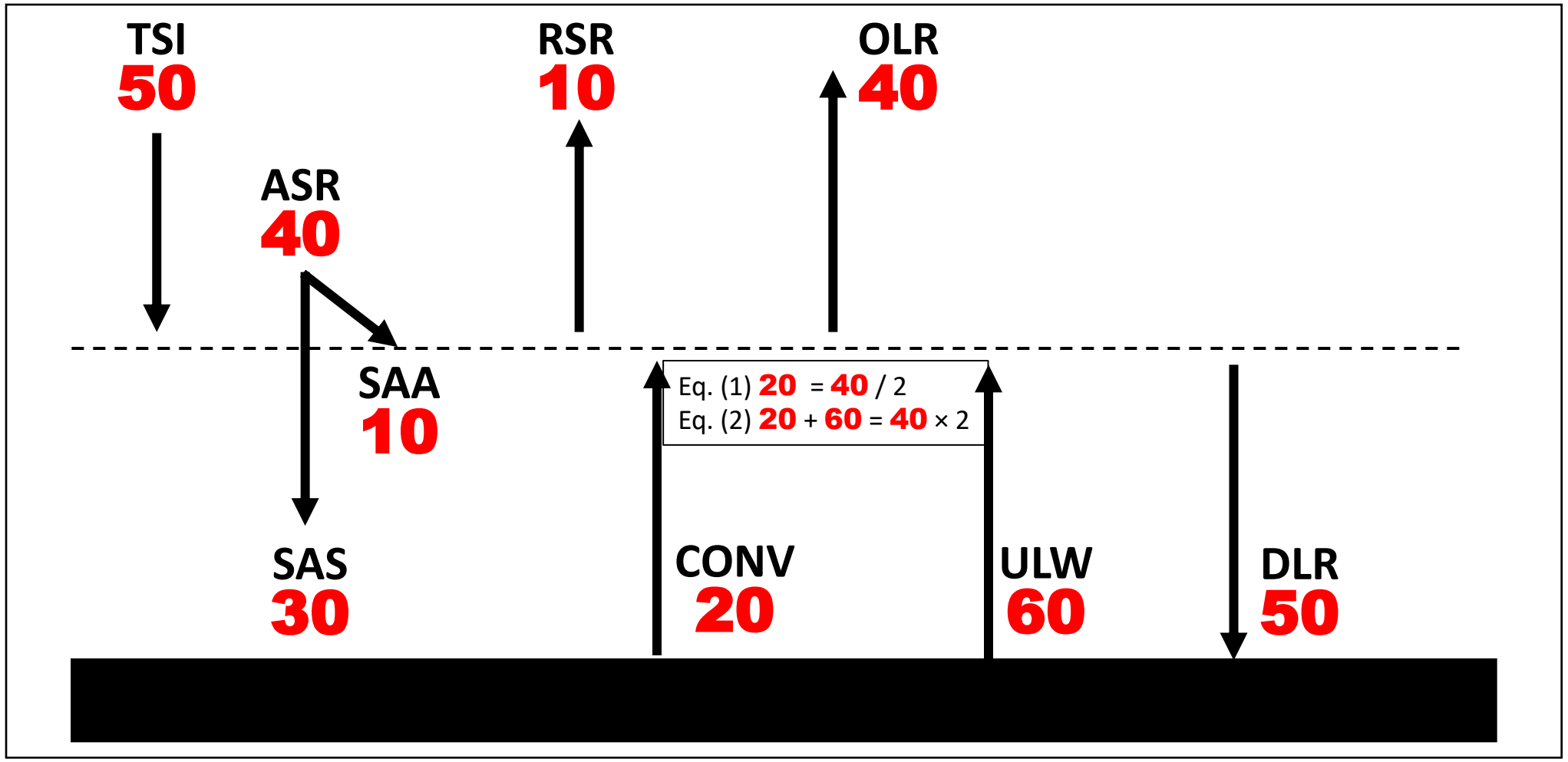
SAS (Solar Abs Surface) will be **3**, DLR will be **5**

Introduce CONV by Eq. (1)



g = 1/3

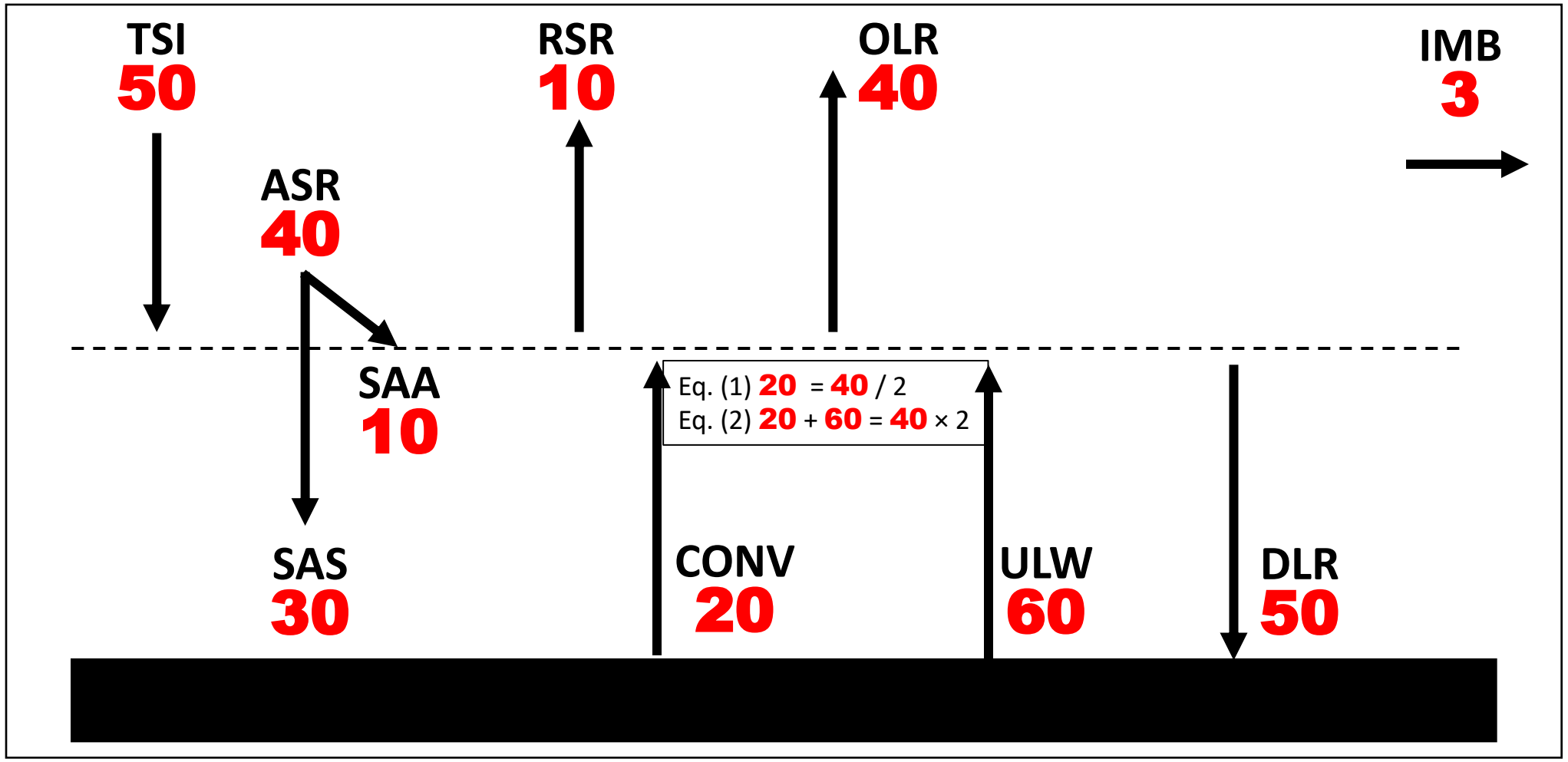
Convert to "red" units, 1 = 10



Before spherical weighting

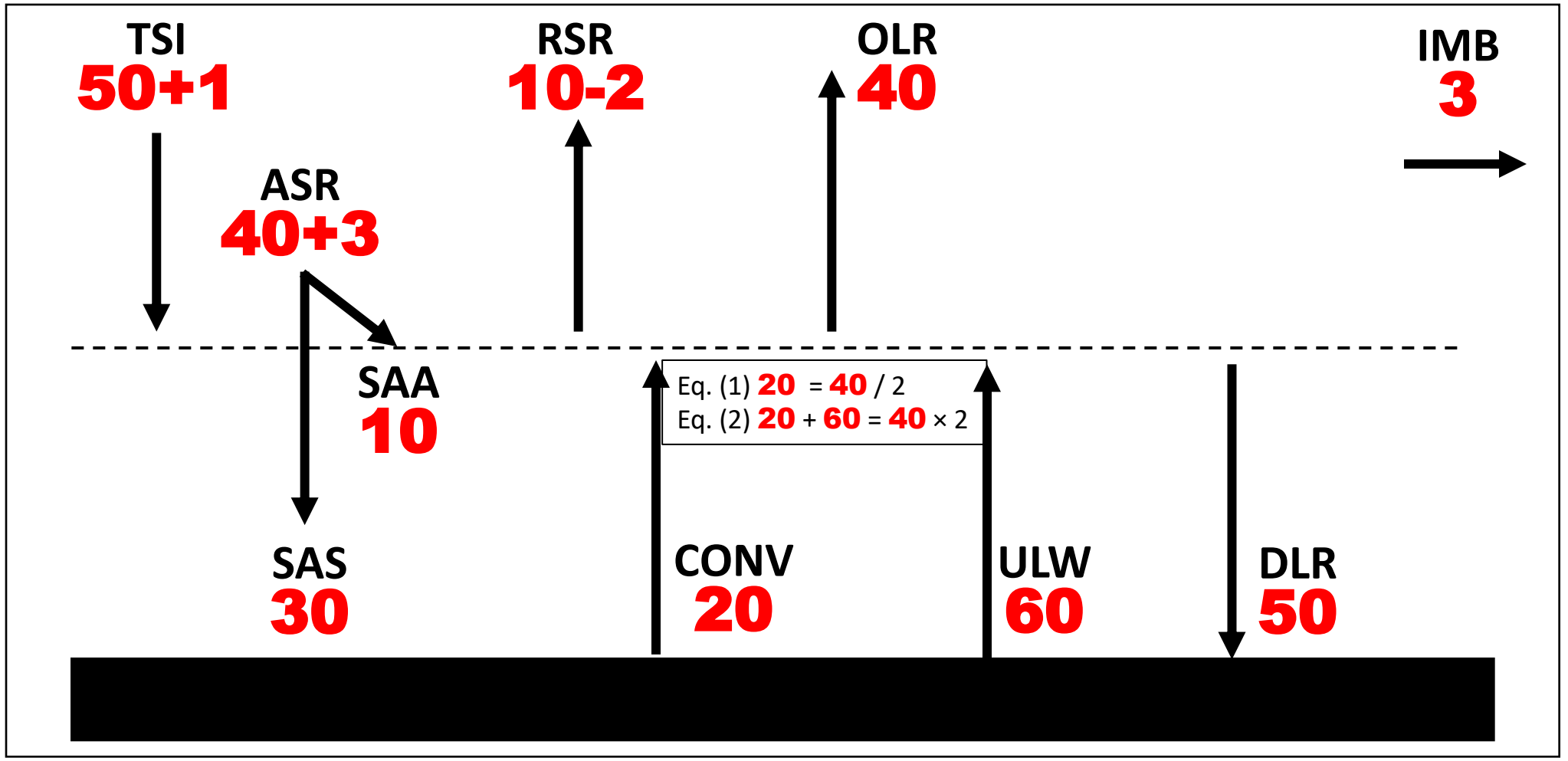
Allow 3 units for Clear-sky TOA imbalance

Wielicki et al. (1995), Wild (2023): Clear TOA IMB = 3/4 = 20 Wm^{-2}



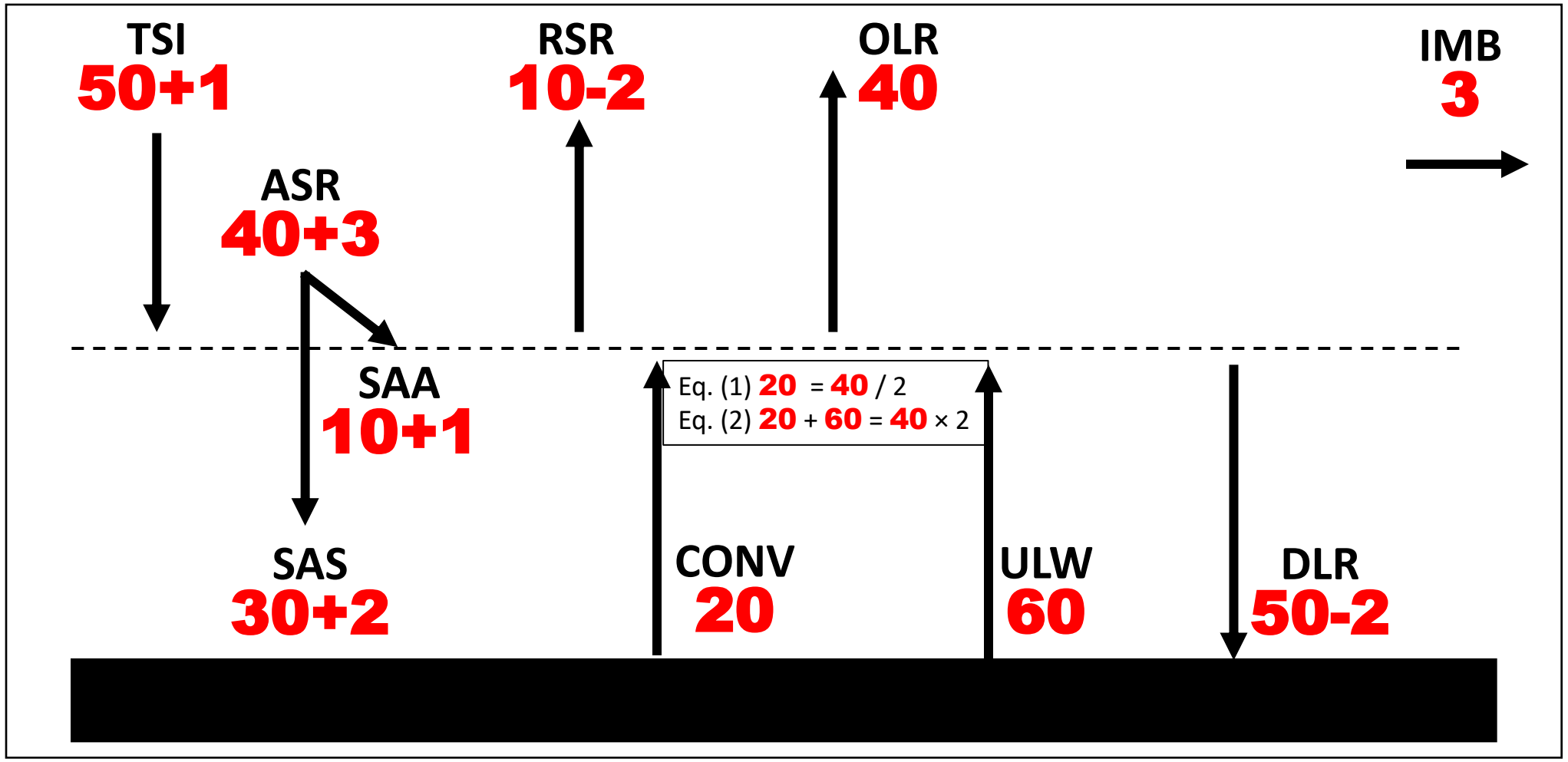
Hiatus 3 is created at TOA

Solving the hiatus: Add 1 to TSI, decrease RSR by 2



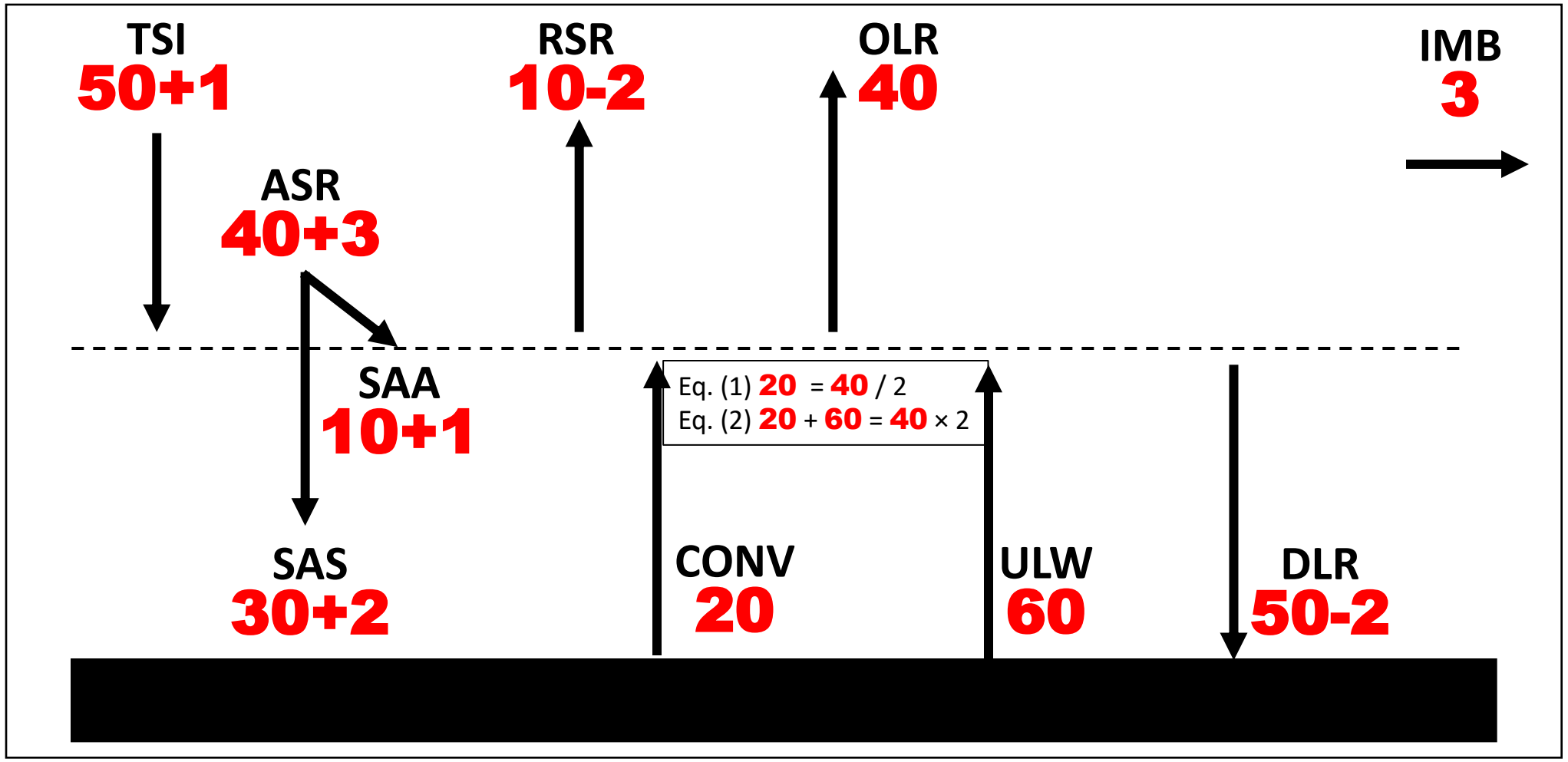
ASR increased by 3

Re-distribute ASR +3 as +1 in atm, +2 at surface



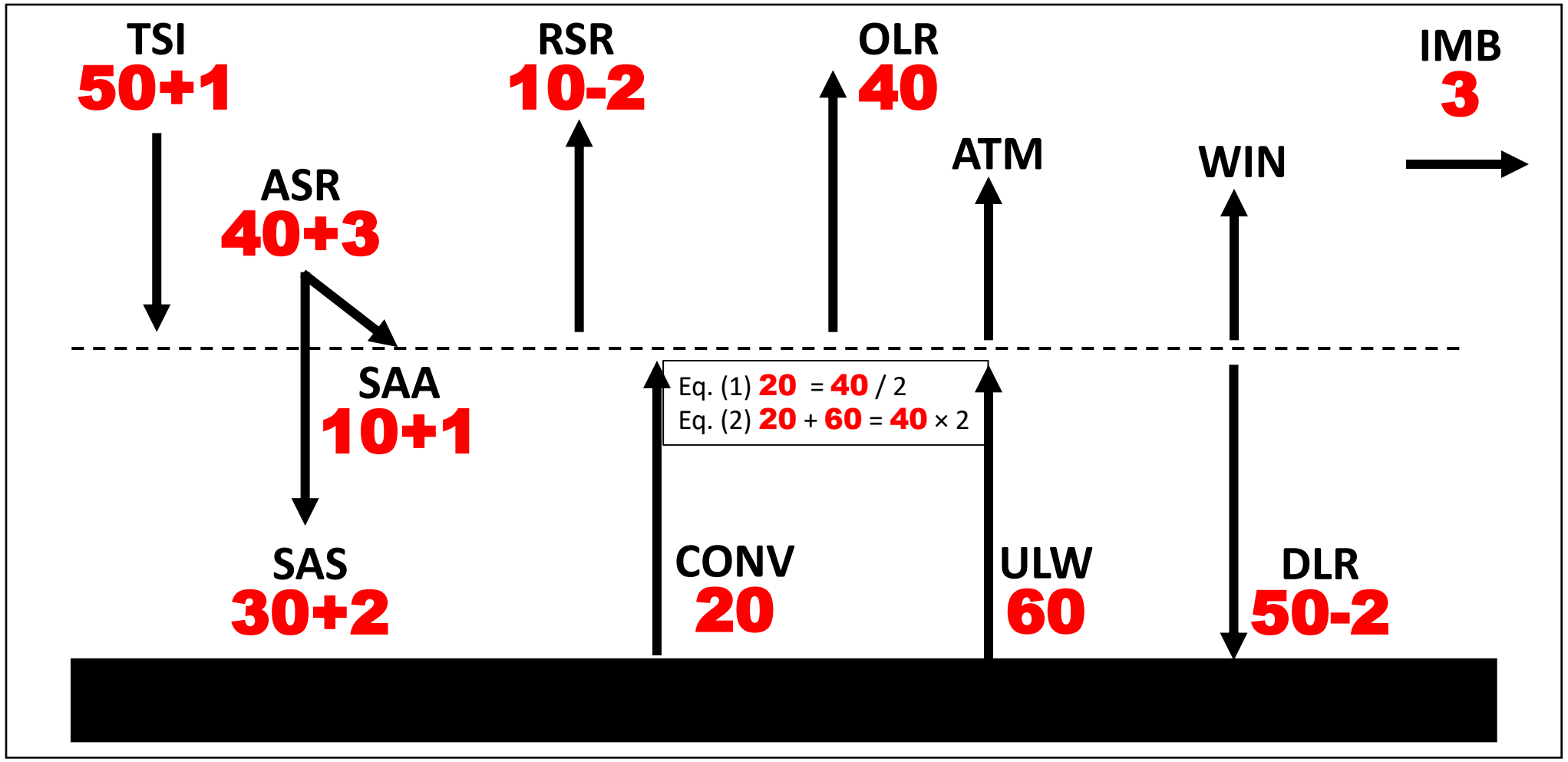
Decrease DLR by 2

Ready. This is the clear-sky system.



On the disk (before spherical weighting)

How much is the window?



A reference in Stephens et al. (2012):

29. Costa, S. M. S. & Shine, K. P. Outgoing longwave radiation due to directly transmitted surface emission *J. Atmos. Sci.* **69,** 1865–1870 (2012).

The spectrally integrated irradiance emitted by the surface is about 386 W m^{-2}, of which 65 W m^{-2} is STI_{clr}. The OLR is about 259 W m^{-2}

A reference in Stephens et al. (2012):

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> The spectrally integrated irradiance emitted by the surface is about 386 W m^{-2}, of which 65 W m^{-2} is STI_{clr}. The OLR is about 259 W m^{-2}

STI_{clr} = 65 Wm^{-2}, OLR = 259 Wm^{-2} => OLR = $4STI_{clr}$

=> Clear-sky unit = STI_{clr} = OLR(clear)/4 = 266.80/4 = 66.70 Wm^{-2} = 10/4 = 1

Clear-sky OLR + G clear) = Surface emission

266.80	133.40	400.20
10	**5**	**15**
4	**2**	**6**

$STI_{clr} = 66.70\ Wm^{-2}$ = **1**

$OLR_{clr} = 266.80\ Wm^{-2}$ = **4**

$G_{clr} = 133.40\ Wm^{-2}$ = **2**

SFC LW up $= 400.20\ Wm^{-2}$ = **6**

Clear-sky unit = STI_{clr} = 266.80/4 = 66.70 Wm^{-2} = 1

Clear-sky OLR	+	G clear)	=	Surface emission
266.80 **10** **4** **6**		133.40 **5** **2** **3**		400.20 **15** **6** **9**

STI_{clr} = 66.70 Wm^{-2} = **1**

OLR_{clr} = 266.80 Wm^{-2} = **4**

G_{clr} = 133.40 Wm^{-2} = **2**

SFC LW up = 400.20 Wm^{-2} = **6**

Clear-sky unit = STI_{clr} = 266.80/4 = 66.70 Wm^{-2} = 1

All-sky unit / Clear-sky unit = 2 / 5 => 2 = 5
All-sky unit / Cloudy unit = 3 / 5 => 3 = 5

"Geometric cloud area fraction" β_g = 3 / 5

Clear-sky OLR	+	G clear)	=	Surface emission
266.80		133.40		400.20
10		**5**		**15**
4		**2**		**6**
6		**3**		**9**

1 = Cloudy unit = LWCRE(total) = OLR (clear) – OLR(cloudy) = LWCRE / β_g = 26.68/0.6 = 44.467 Wm^{-2}

Clear-sky OLR (**6**) – $LWCRE_{total}$ (**1**) = Cloudy OLR (**5**)

OLR(cloudy) = **5** = 266.80 – 44.467 = 222.33 Wm^{-2} (FluxByCldTyp?)

CERES_EBAF_Ed4.2.1_Subset_200004-202603.nc (26 years)

301	401,2489	265,4551	135,7938	0,338427844
302	405,2417	267,0644	138,1773	0,340975028
303	408,5014	268,9221	139,5793	0,341686222
304	410,0806	269,913	140,1676	0,341805001
305	409,1639	269,5647	139,5992	0,341181615
306	406,6477	268,4265	138,2212	0,33990405
307	401,3641	266,4104	134,9537	0,336237596
308	395,3934	264,207	131,1864	0,331787025
309	392,0032	262,8878	129,1154	0,329373332
310	391,6581	263,0665	128,5916	0,32832616
311	393,0814	263,744	129,3374	0,329034648
312	396,7196	264,2255	132,4941	0,333974172
313	gsfc_lw_up_clr	gtoa_lw-up_clr	G	g
314	**399,00681**	**266,00641**	**133,00041**	**0,33333**

Clear-sky	N	Clear-sky unit STI_{clr} = 66.5	Cloudy-sky unit $LWCRE_{full}$= 44.3	All-sky unit LWCRE = 26.6	Geometry	CERES
Surface LW up	**3**	**6**	**9**	**15**	399	399.0068
TOA LW up	**2**	**4**	**6**	**10**	266	266.0064
G	**1**	**2**	**3**	**5**	133	133.0004
g	1/3	1/3	1/3	1/3	1/3	0.33333

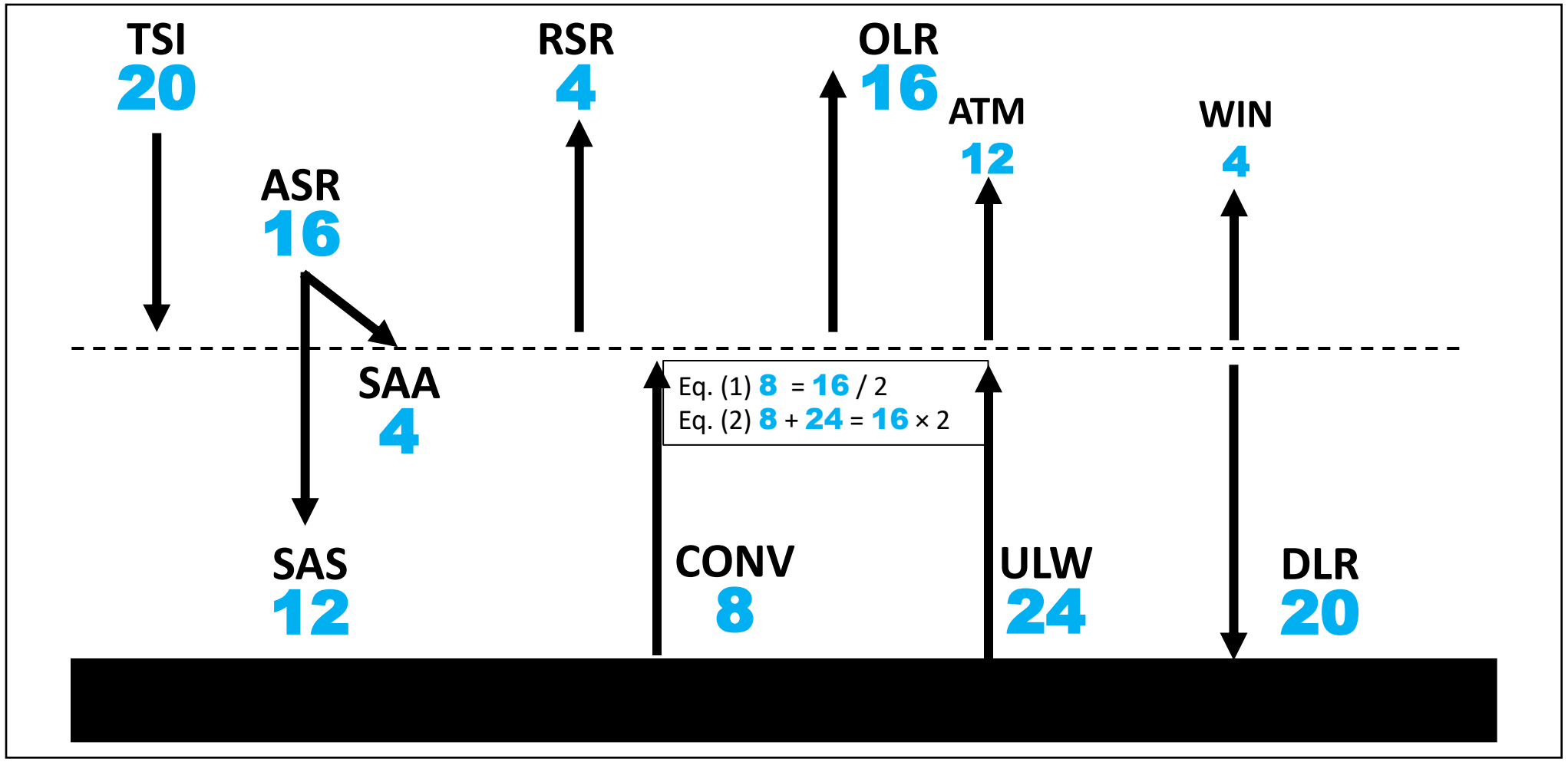
CERES_EBAF_Ed4.2.1_Subset_200004-202603.nc (26 years)

301	401,2489	265,4551	135,7938	0,338427844
302	405,2417	267,0644	138,1773	0,340975028
303	408,5014	268,9221	139,5793	0,341686222
304	410,0806	269,913	140,1676	0,341805001
305	409,1639	269,5647	139,5992	0,341181615
306	406,6477	268,4265	138,2212	0,33990405
307	401,3641	266,4104	134,9537	0,336237596
308	395,3934	264,207	131,1864	0,331787025
309	392,0032	262,8878	129,1154	0,329373332
310	391,6581	263,0665	128,5916	0,32832616
311	393,0814	263,744	129,3374	0,329034648
312	396,7196	264,2255	132,4941	0,333974172
313	gsfc_lw_up_clr	gtoa_lw-up_clr	G	g
314	**399,00681**	**266,00641**	**133,00041**	**0,33333**

This is one of my (or, dear CERES Science Team, our) most important slides ever

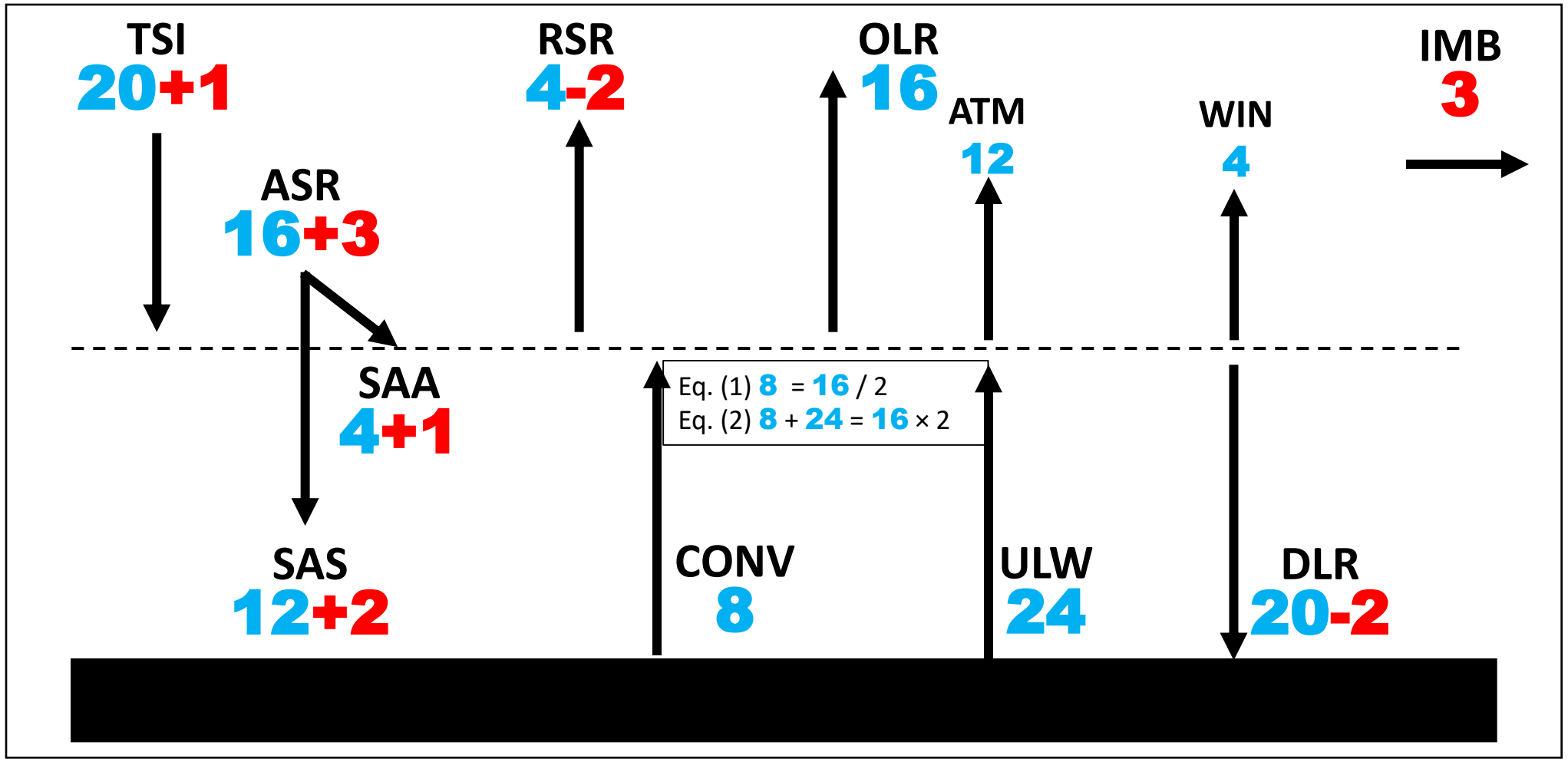
Clear-sky	N	Clear-sky unit STI_{clr} = 66.5	Cloudy-sky unit $LWCRE_{full}$= 44.3	All-sky unit LWCRE = 26.6	Geometry Set 1	CERES Set 2
Surface LW up	**3**	**6**	**9**	**15**	399	399.0068
TOA LW up	**2**	**4**	**6**	**10**	266	266.0064
G	**1**	**2**	**3**	**5**	133	133.0004
g	1/3	1/3	1/3	1/3	1/3	0.33333

The clear-sky system, in its own units, without transfer



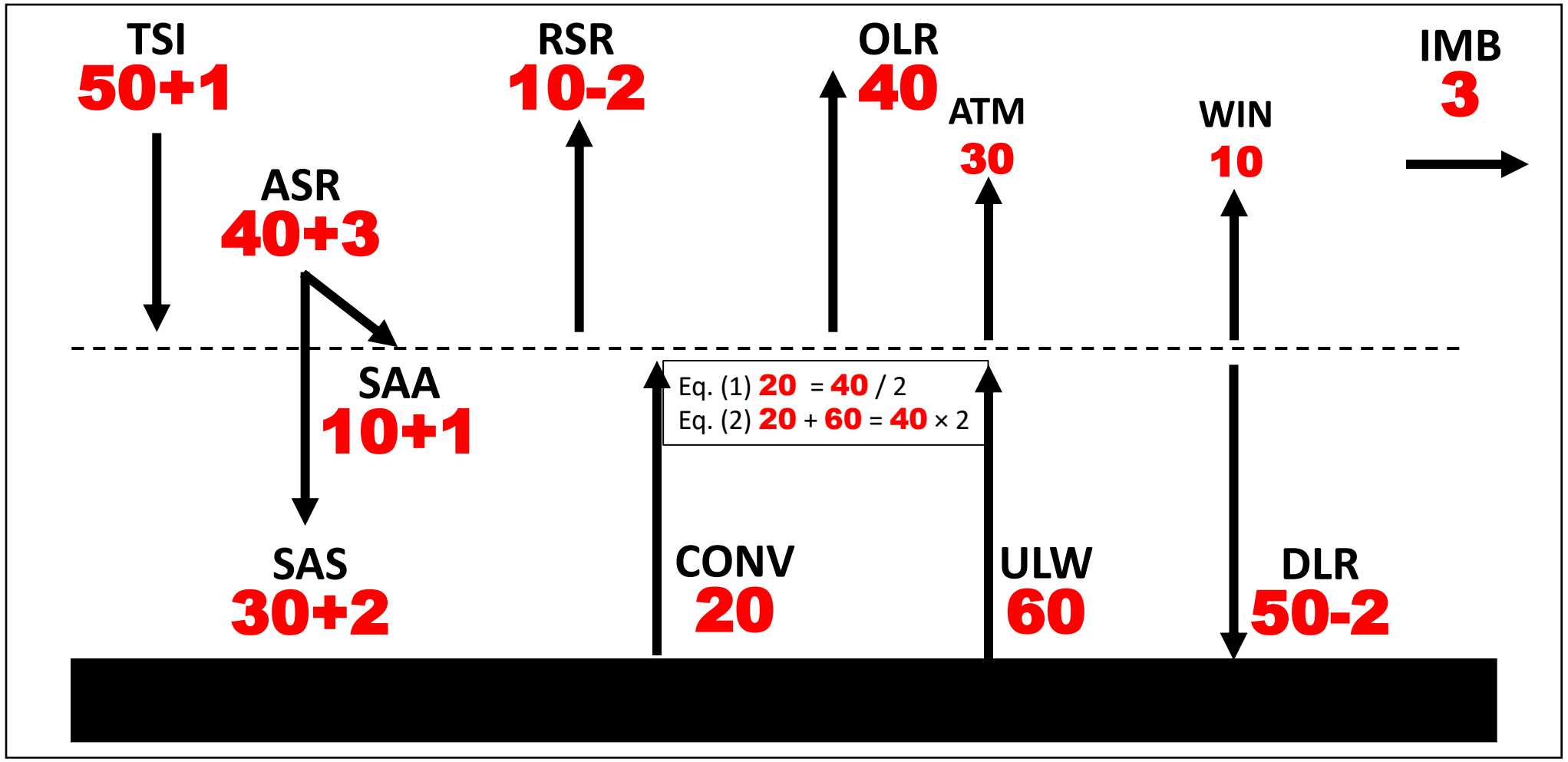
g = 1/3

The clear-sky system, with energy transfer



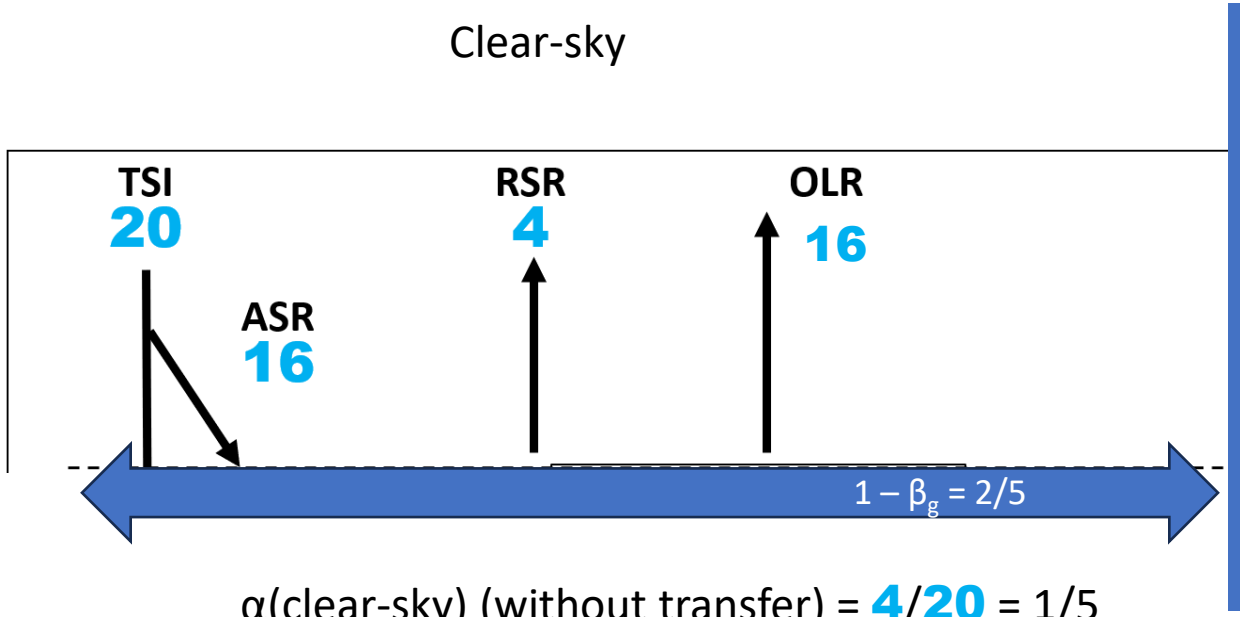
g = 1/3

The clear-sky system, in "red" units



On the disk (before spherical weighting)

The clear-sky system, without transfer

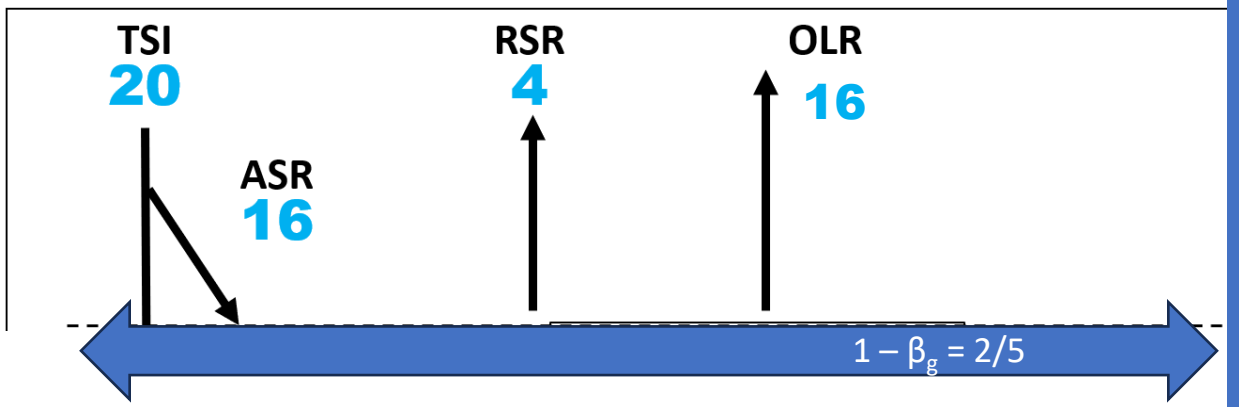


α(clear-sky) (without transfer) = **4**/**20** = 1/5

Clear-sky contribution = $\frac{1}{5} \times \frac{2}{5} = \frac{2}{25}$

Define cloudy albedo as 1/3

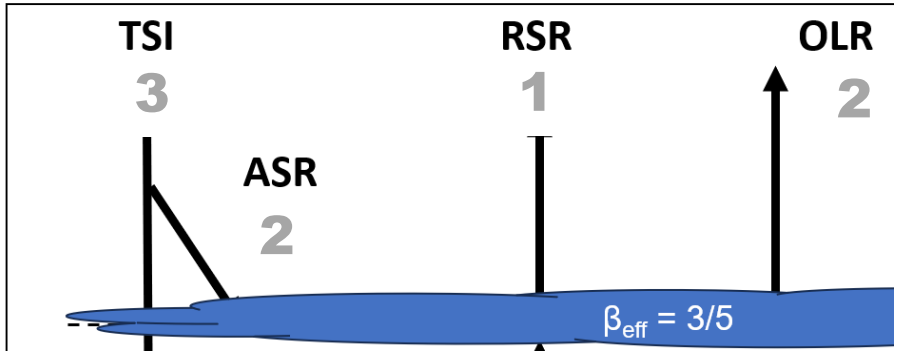
Clear-sky



α(clear-sky) (without transfer) = **4**/**20** = 1/5

Clear-sky contribution = $\frac{1}{5} \times \frac{2}{5} = \frac{2}{25}$

Cloudy sky

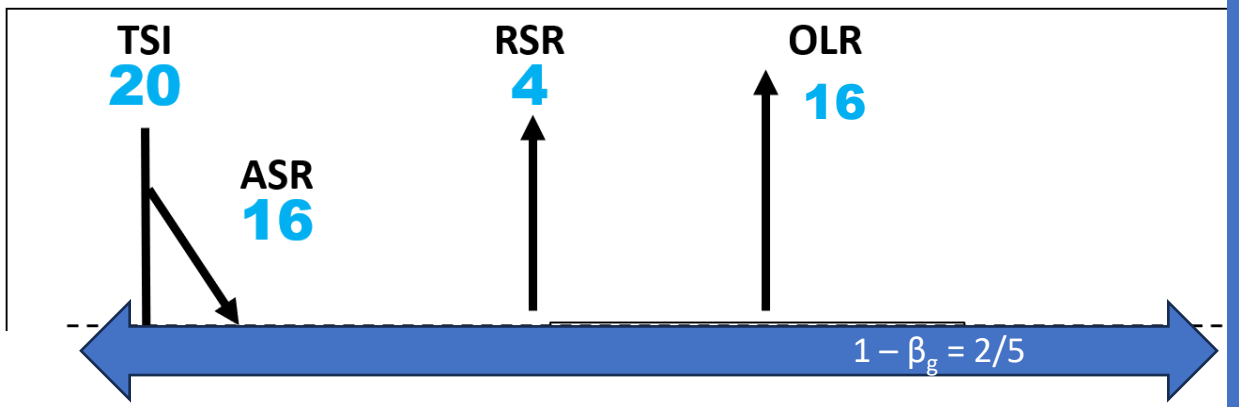


α(cloudy-sky) (without transfer) = **1**/**3**

Cloudy contribution $= \frac{1}{3} \times \frac{3}{5} = \frac{1}{5} = \frac{5}{25}$

Convert to cloudy units

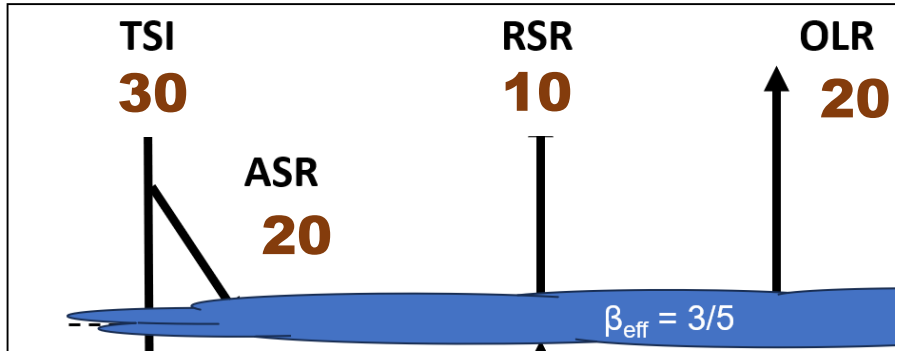
Clear-sky



α(clear-sky) (without transfer) = **4**/**20** = 1/5

Clear-sky contribution = $\frac{1}{5} \times \frac{2}{5} = \frac{2}{25}$

Cloudy sky

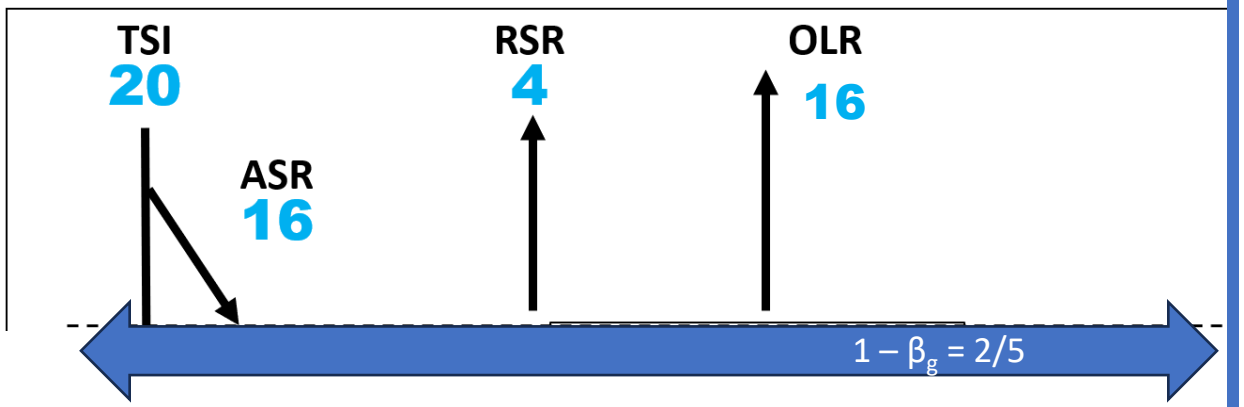


α(cloudy-sky) (without transfer) = **10**/**30** = 1/3

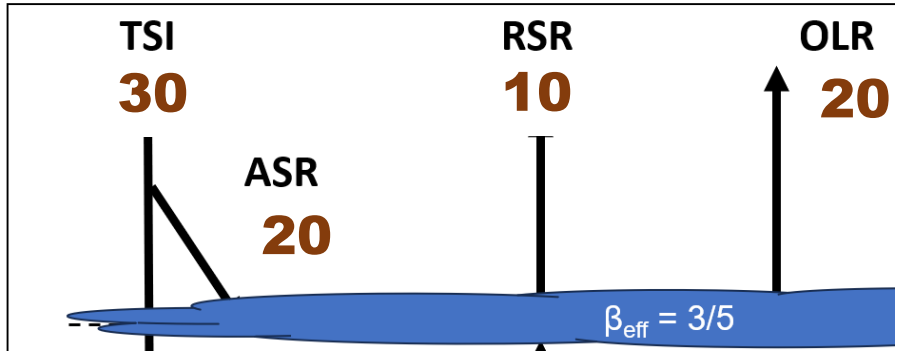
Cloudy contribution $= \frac{1}{3} \times \frac{3}{5} = \frac{1}{5} = \frac{5}{25}$

The all-sky albedo, without transfer

Clear-sky



Cloudy sky



α(clear-sky) (without transfer) = **4**/**20** = 1/5

α(cloudy-sky) (without transfer) = **10**/**30** = 1/3

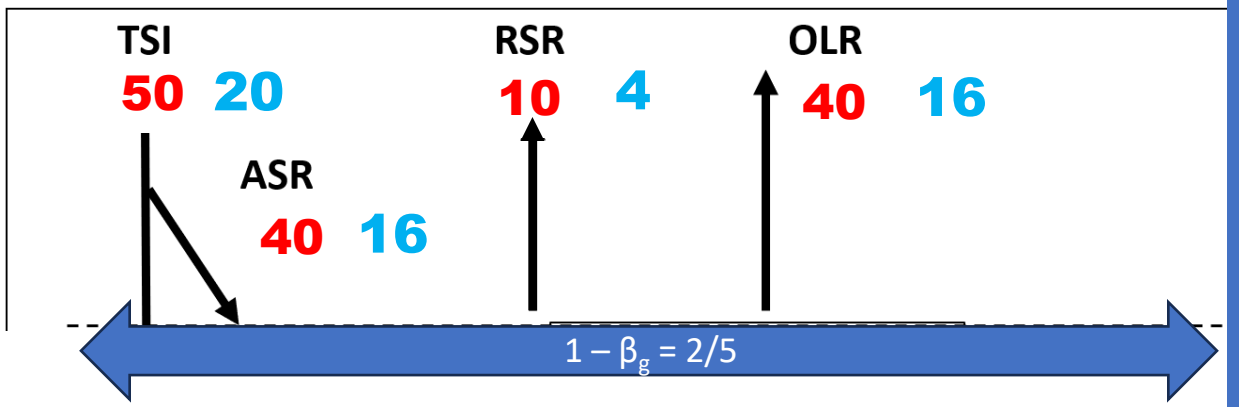
Clear-sky contribution = $\frac{1}{5} \times \frac{2}{5} = \frac{2}{25}$

Cloudy contribution $= \frac{1}{3} \times \frac{3}{5} = \frac{1}{5} = \frac{5}{25}$

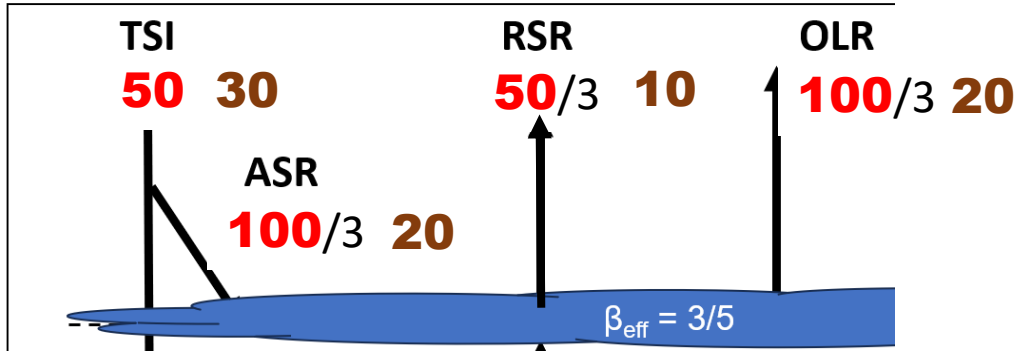
All-sky albedo (without transfer) = $\frac{2}{25} + \frac{5}{25} = \frac{7}{25} = 0.280$

Convert to "red" units

Clear-sky



Cloudy sky



α(clear-sky) (without transfer) = **10**/**50** = 1/5

α(cloudy-sky) (without transfer) = (**50**/3)/**50** = 1/3

Clear-sky contribution = $\frac{1}{5} \times \frac{2}{5} = \frac{2}{25}$

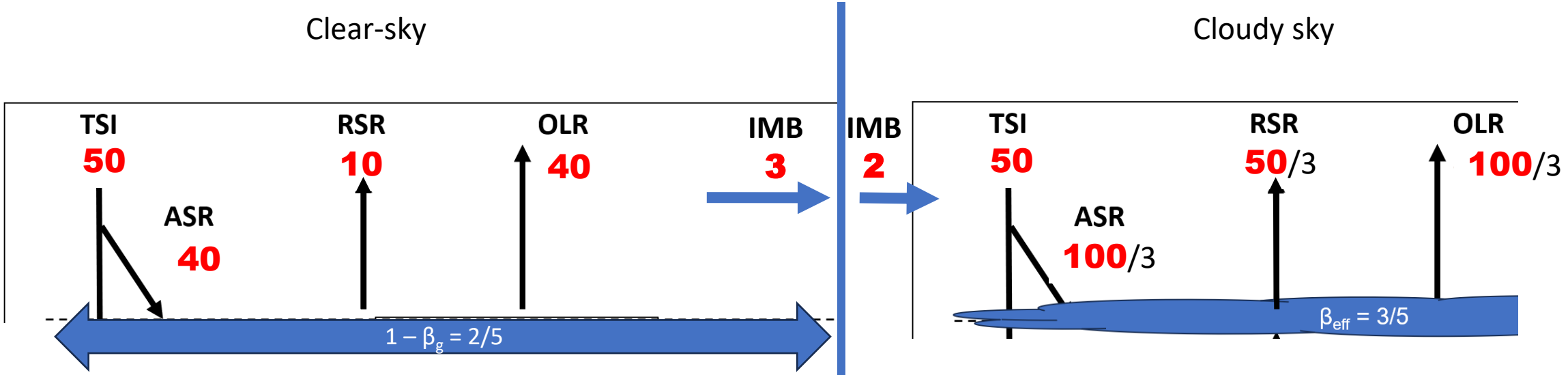
Cloudy contribution = $\frac{1}{3} \times \frac{3}{5} = \frac{1}{5} = \frac{5}{25}$

4 = **10**
16 = **40**
20 = **50**

All-sky albedo (without transfer) = $\frac{2}{25} + \frac{5}{25} = \frac{7}{25} = 0.280$

10 = **50**/3
20 = **100**/3
30 = **50**

Allow IMB (energy transfer from clear to cloudy)



α(clear-sky) (without transfer) = **10**/**50** = 1/5

α(cloudy-sky) (without transfer) = (**50**/3)/**50** = 1/3

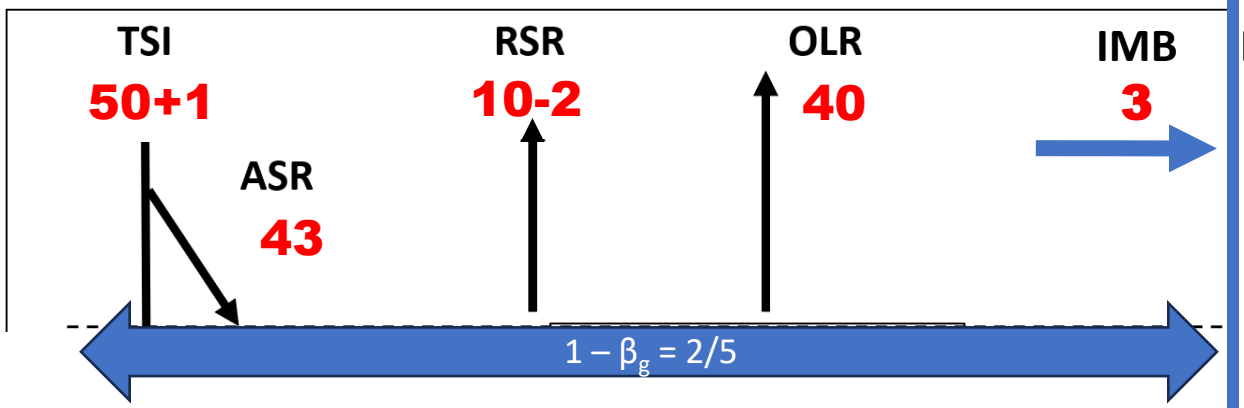
Clear-sky contribution = $\frac{1}{5} \times \frac{2}{5} = \frac{2}{25}$

Cloudy contribution $= \frac{1}{3} \times \frac{3}{5} = \frac{1}{5} = \frac{5}{25}$

All-sky albedo (without transfer) = $\frac{2}{25} + \frac{5}{25} = \frac{7}{25} = 0.280$

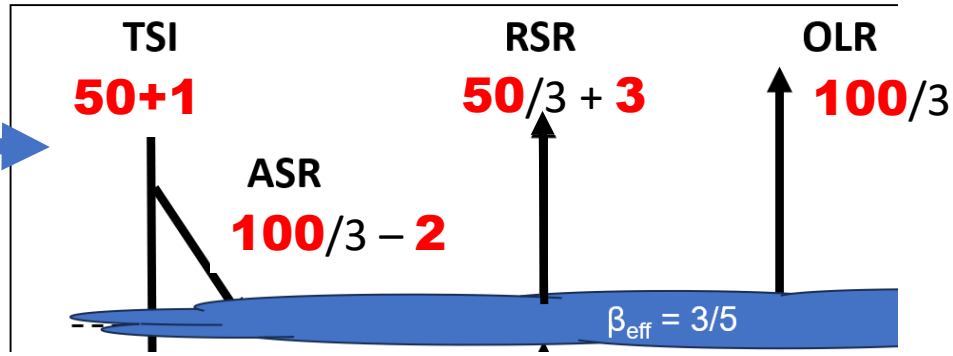
Re-distribute IMB

Clear-sky: **+1** to TSI, **–2** from RSR



IMB
2

Cloudy: **+1** to TSI, **+3** to RSR



α(clear-sky) = **8**/**51**

α(cloudy) = (**50**/3 + **3**)/**51** = (**59**/3)/**51**

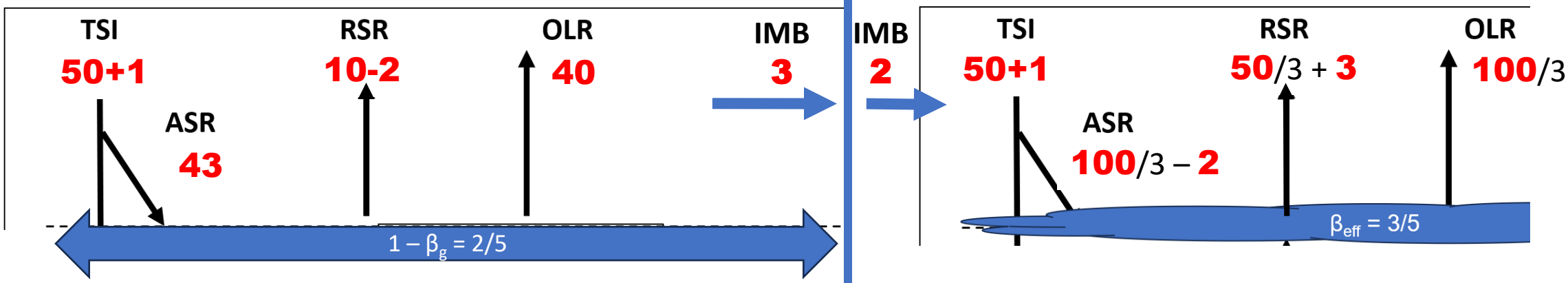
Clear-sky contribution = $\frac{8}{51} \times \frac{2}{5} = \frac{16}{5} \times \frac{1}{51}$

Cloudy contribution = $\frac{59}{3} \times \frac{1}{51} \times \frac{3}{5} = \frac{59}{5} \times \frac{1}{51}$

The all-sky albedo.

Clear-sky: **+1** to TSI, **–2** from RSR

Cloudy: **+1** to TSI, **+3** to RSR



α(clear-sky) = **8**/**51**

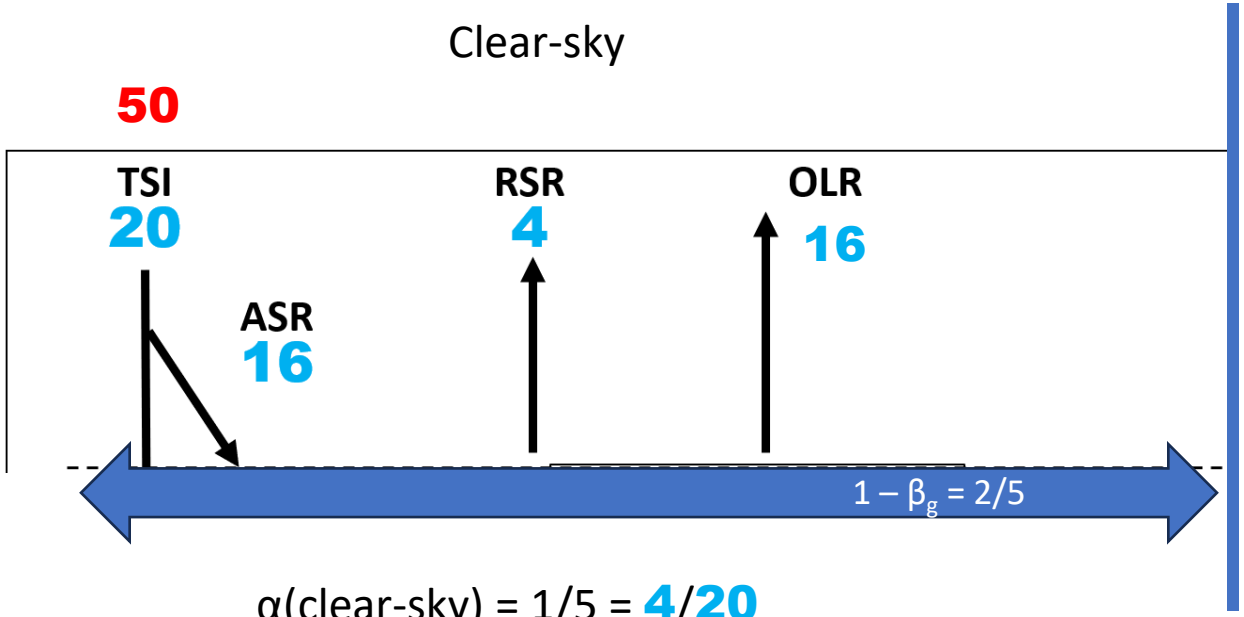
α(cloudy) = (**50**/3 + **3**)/**51** = (**59**/3)/**51**

Clear-sky contribution = $\frac{8}{51} \times \frac{2}{5} = \frac{16}{5} \times \frac{1}{51}$

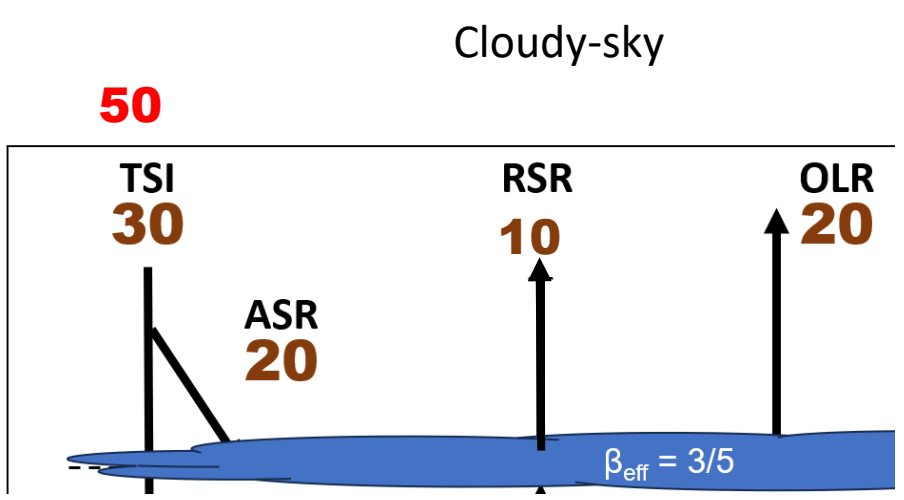
Cloudy contribution = $\frac{59}{3} \times \frac{1}{51} \times \frac{3}{5} = \frac{59}{5} \times \frac{1}{51}$

All-sky albedo = $\frac{16}{5} \times \frac{1}{51} + \frac{59}{5} \times \frac{1}{51} = \frac{75}{5} \times \frac{1}{51}$ = **15**/**51** = 0.294

In their own units, without transfer



α(clear-sky) = 1/5 = **4**/**20**



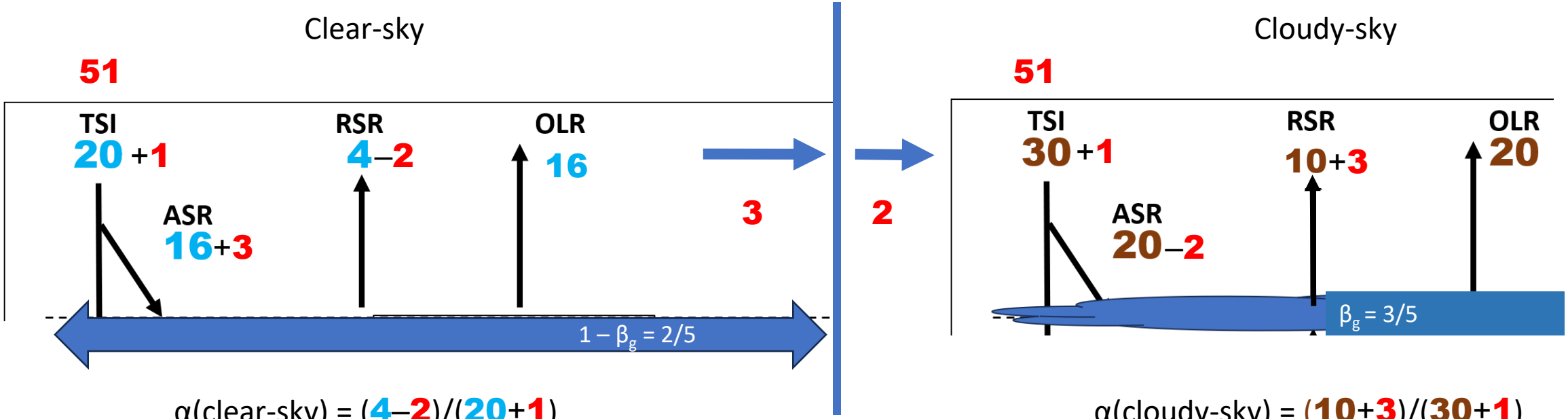
α(cloudy-sky) = 1/3 = **10**/**30**

TSI = 1361.84 Wm^{-2}
= **51**
=> **1** = 66.70 Wm^{-2}
=> **1** = 44.46 Wm^{-2}
=> **1** = 26.68 Wm^{-2}

α(all-sky) [without transfer] = $\frac{4}{20} \times \frac{2}{5} + \frac{10}{30} \times \frac{3}{5} = 14/50 = \mathbf{14}/\mathbf{50} = 0.280$

TSI = 1361.84 Wm^{-2}
= **51**
= **20** + **1**
= **30** + **1**
= **50** + **1**

In their own units, with energy transfer



α(clear-sky) = (4–2)/(20+1)

α(cloudy-sky) = (10+3)/(30+1)

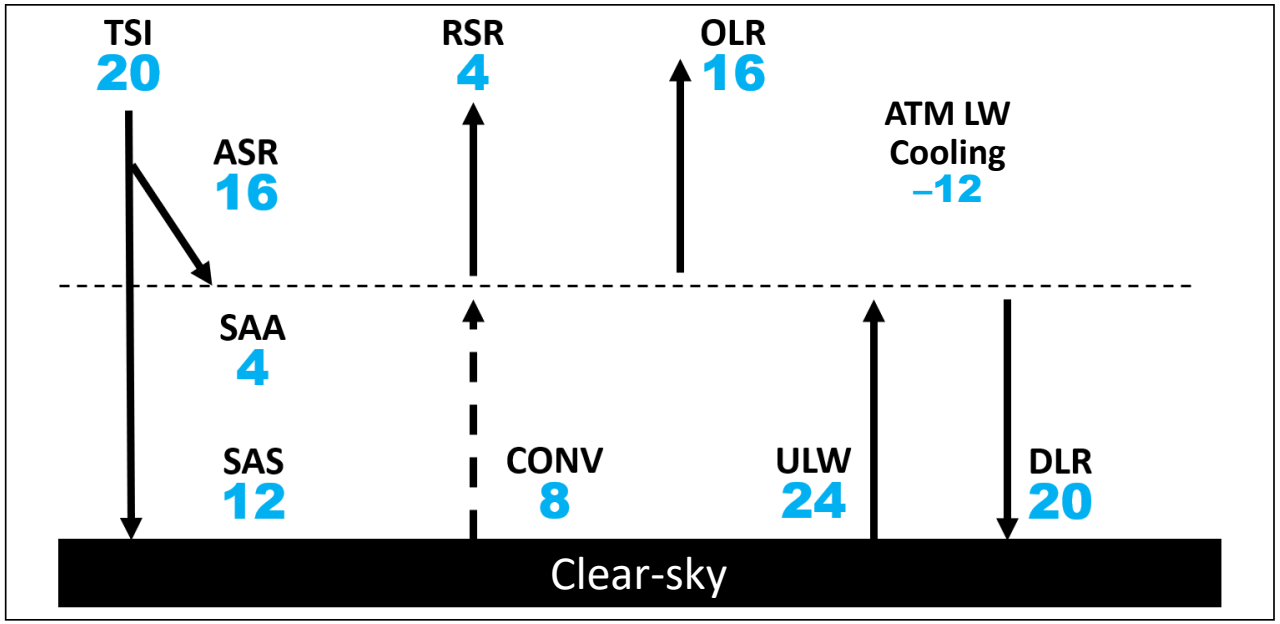
TSI = 1361.84 Wm^{-2}
= **51**
=> **1** = 66.70 Wm^{-2}
=> **1** = 44.46 Wm^{-2}
=> **1** = 26.68 Wm^{-2}

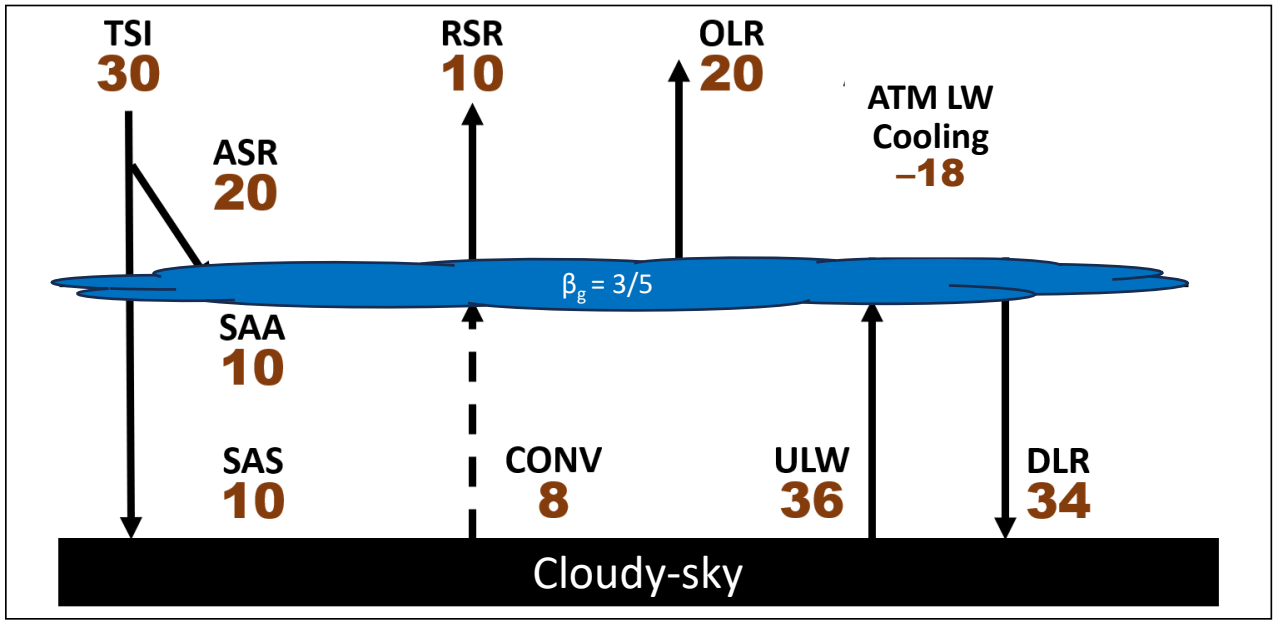
α(all-sky) [without transfer] = $\frac{4}{20}\times\frac{2}{5}+\frac{10}{30}\times\frac{3}{5}=14/50=$ **14**/**50** $=0.280$

α(all-sky) = $\frac{8}{51}\times\frac{2}{5}+\frac{59}{3}\times\frac{1}{51}\times\frac{3}{5}=(\frac{16}{5}+\frac{59}{5})/51=\frac{75}{5}/51=$ **15**/**51** $=0.294$

TSI = 1361.84 Wm^{-2}
= **51**
= **20** + **1**
= **30** + **1**
= **50** + **1**

Units on the disk, without transfer

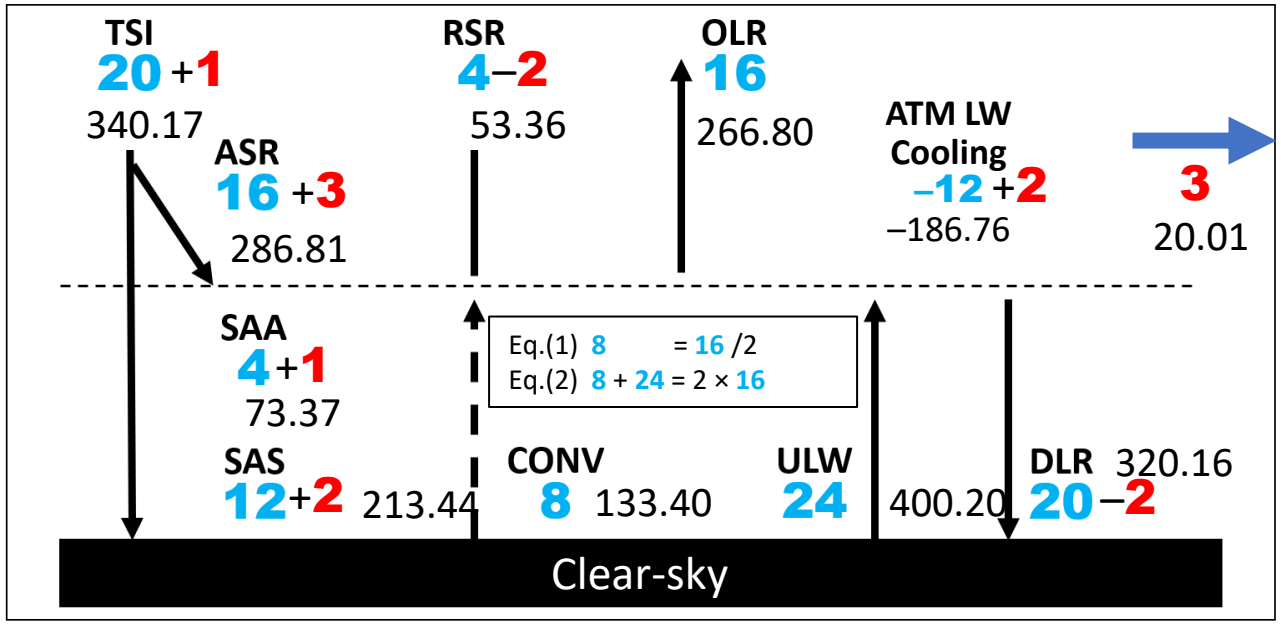


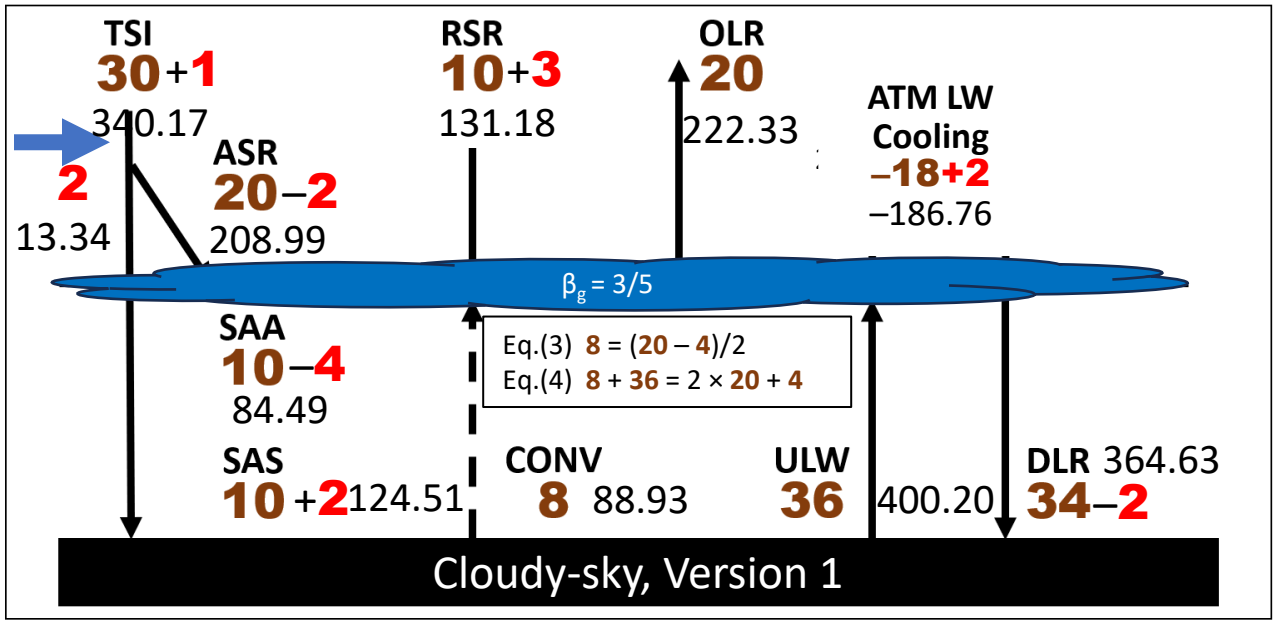


SW reflection = 1/5
SW absorption = 1/5
SW transmission = 3/5

SW reflection = 1/3
SW absorption = 1/3
SW transmission = 1/3

Units on the disk, with transfer

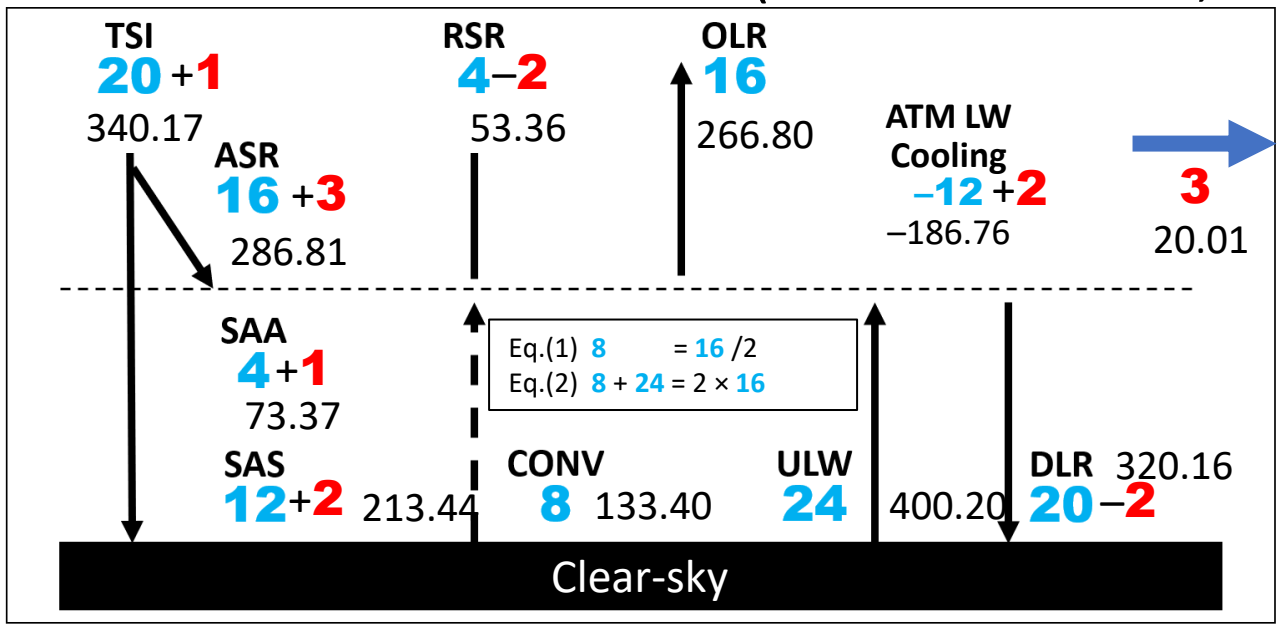


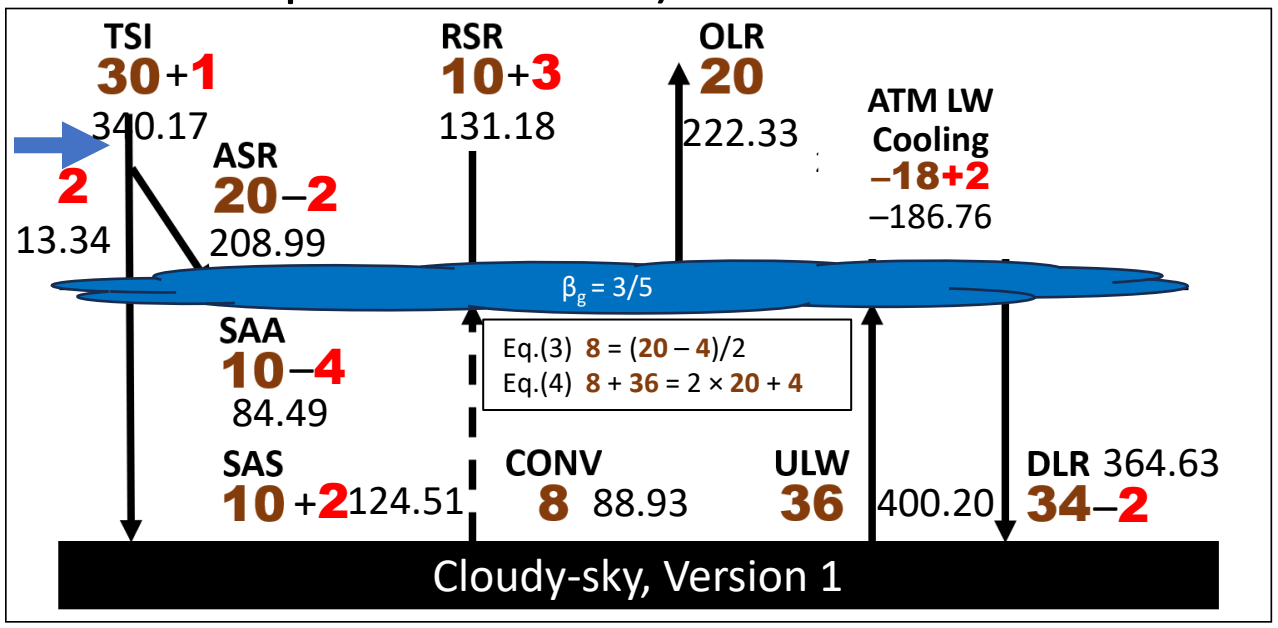


SW reflection = (4 – 2) / 51 = 8 / 51
SW absorption = (4 + 1) / 51 = 11 / 51
SW transmission= (12 + 2) / 51 = 32 / 51

SW reflection = (10 + 3)/ 51 = (20 – 1/3) / 51
SW absorption = (10 – 4)/ 51 = (13 – 1/3) / 51
SW transmission = (10 + 2)/ 51 = (19 – 1/3) / 51

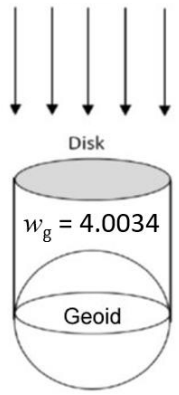
Set 1 (units on the disk, data on the sphere in Wm^{-2})

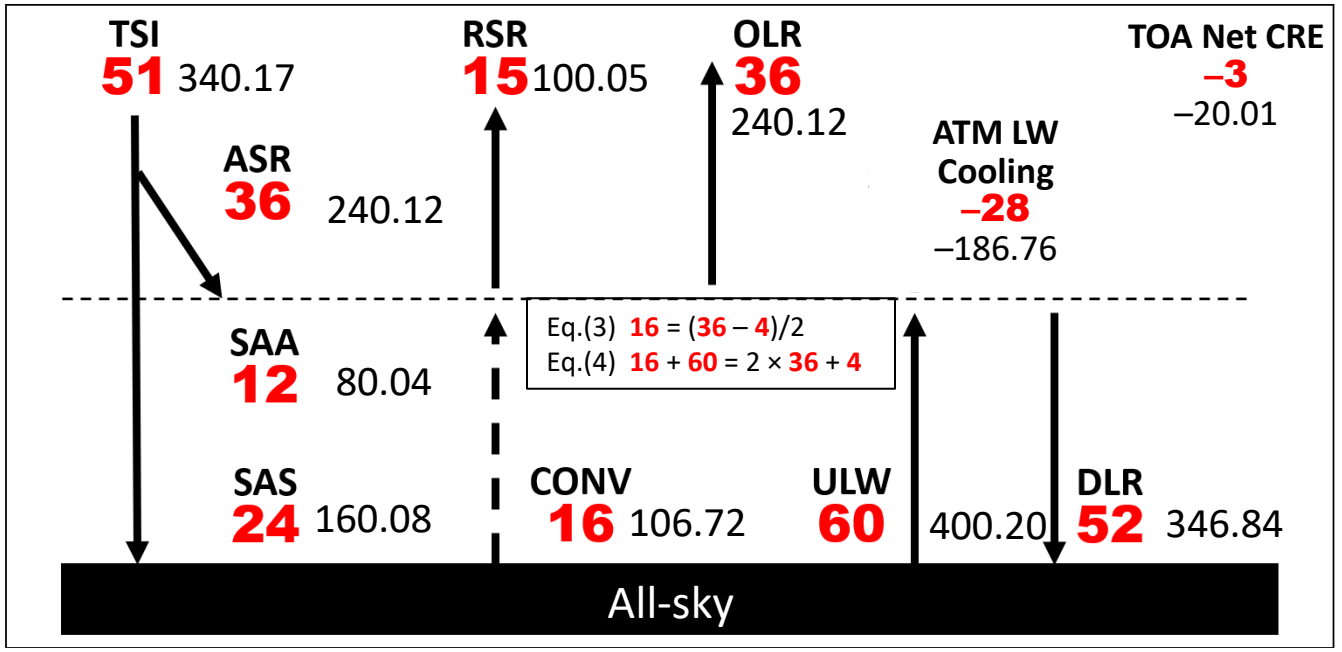




The only input parameter is TSI

51





TSI = 1361.84 Wm^{-2}
= **51**
= **20** + **1**
= **30** + **1**
= **50** + **1**

ULW = **6** = **9** = **15** = 400.2 Wm^{-2}

1 = 66.70 Wm^{-2}
1 = 44.46 Wm^{-2}
1 = 26.68 Wm^{-2}

(geodetic weighting factor = 4.0034)