EBAF Ed4.2 vs 4.1 & TOA SW Up

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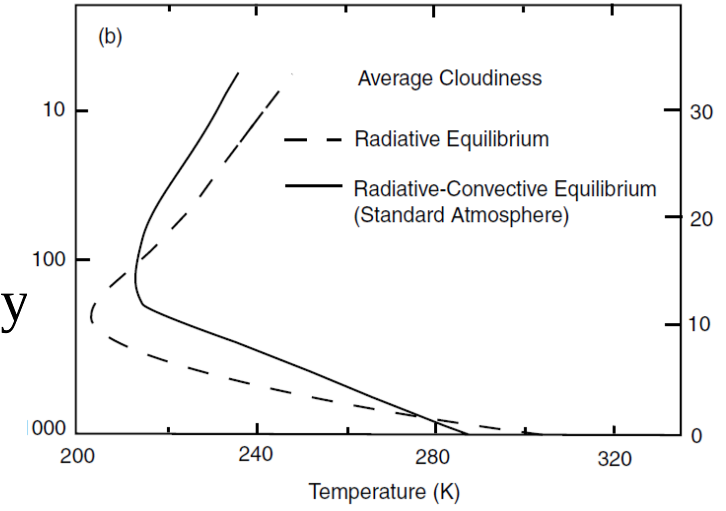
(Remote Presentation)

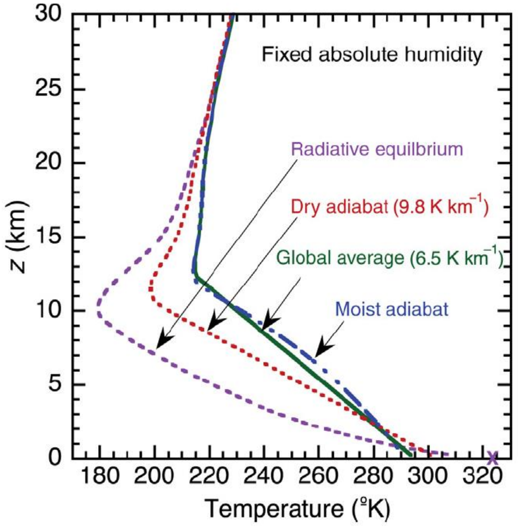
$$E = \frac{A_0}{2}(1 + \bar{\tau}), \qquad A = \frac{A_0}{2}(2 + \bar{\tau}), \qquad B = \frac{A_0}{2}\bar{\tau}. \qquad (11)$$

Schwarzschild (1906, Eq. 11)

E	emission of a layer
A	upward beam at the given layer
B	downward beam at that layer
A_0	emerging beam at the upper boundary
τ	optical depth



Liou (2002, Fig. 8.9)



Hartmann (2016, Fig. 3.16)

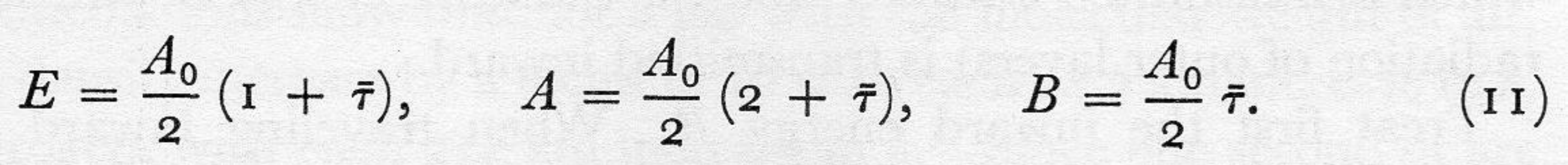
Net radiation at the surface:

Eq. (1) $A - E = SH + LH = A_0/2$

May be derived from first principles (Milne 1930, Handbook of Astrophysics)

Represented in: Ostriker (1963, Eq. 15); Goody (1964, Eq. 2.115); Houghton (1977, Eq. 2.13); Chamberlain (1978, Eq. 1.2.29); Goody and Yung (1989, 2.146); Stephens (1991, Eq. 1 & 2; 1994, Eq. 5a & 5b); Hartmann (1994, Fig. 3.10-3.11); Liou (2002, Fig. 8.9); Pierrehumbert (2010, Eq. 4.44-4.45); Hartmann (2016, Fig. 3.16) …

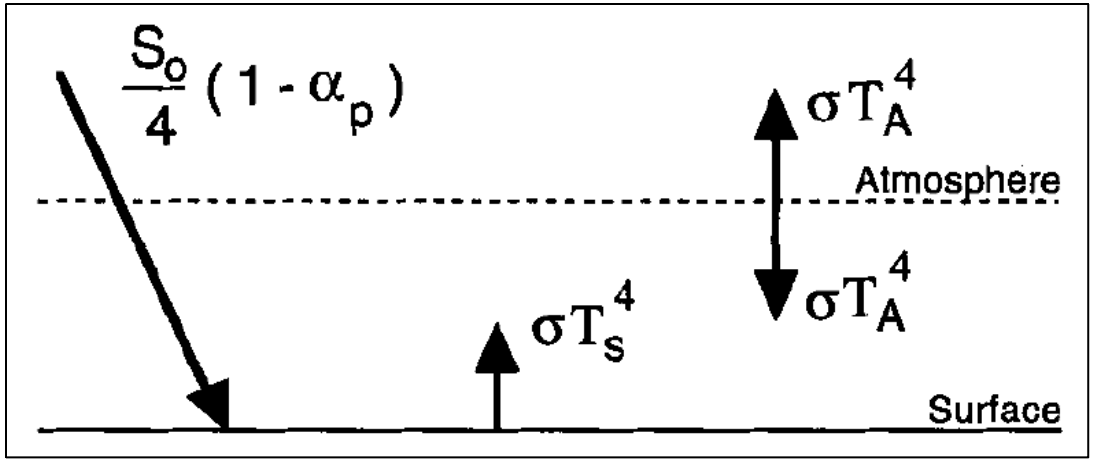
I think my study is the first that controls it on global mean observed data.



$$E = \frac{A_0}{2}(1 + \bar{\tau}), \qquad A = \frac{A_0}{2}(2 + \bar{\tau}), \qquad B = \frac{A_0}{2}\bar{\tau}. \qquad (11)$$

Eq. (2) $A = 2A_0$ at $\tau = 2$

2.5 Greenhouse Effect



Hartmann (1994, Fig. 2.3) $\sigma T_S^4 = 2\sigma T_A^4$

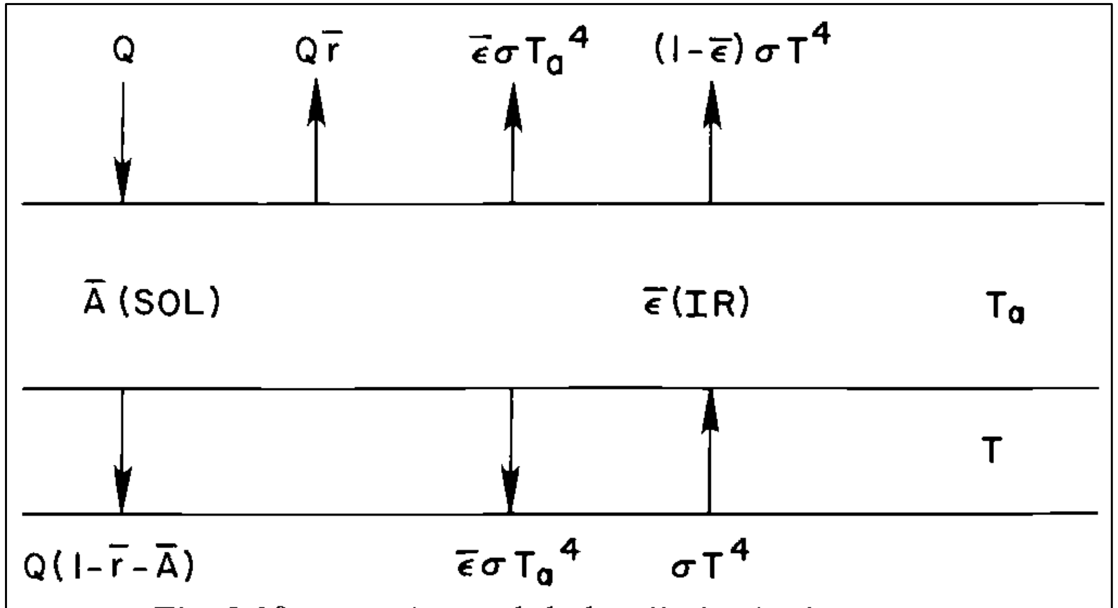


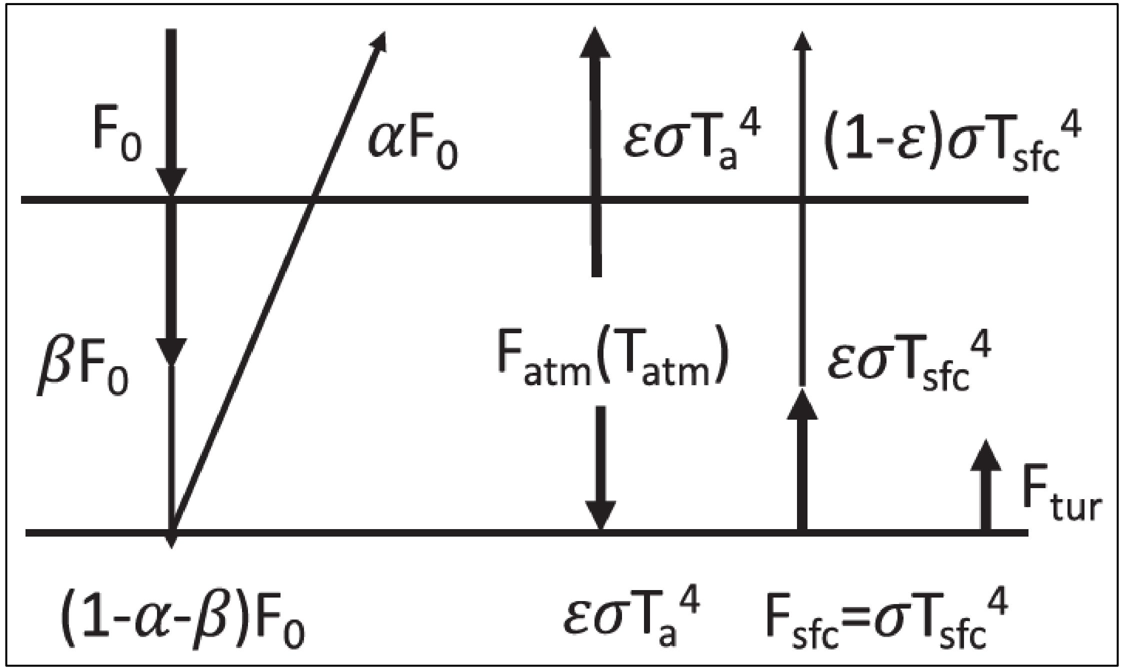
Fig. 8.20 Two-layer global radiative budget model.

Liou (1980, Fig. 8.20) $\epsilon = 1 \Rightarrow \sigma T^4 = 2\sigma T_a^4$

Total radiation at the surface if $\epsilon = 1$:

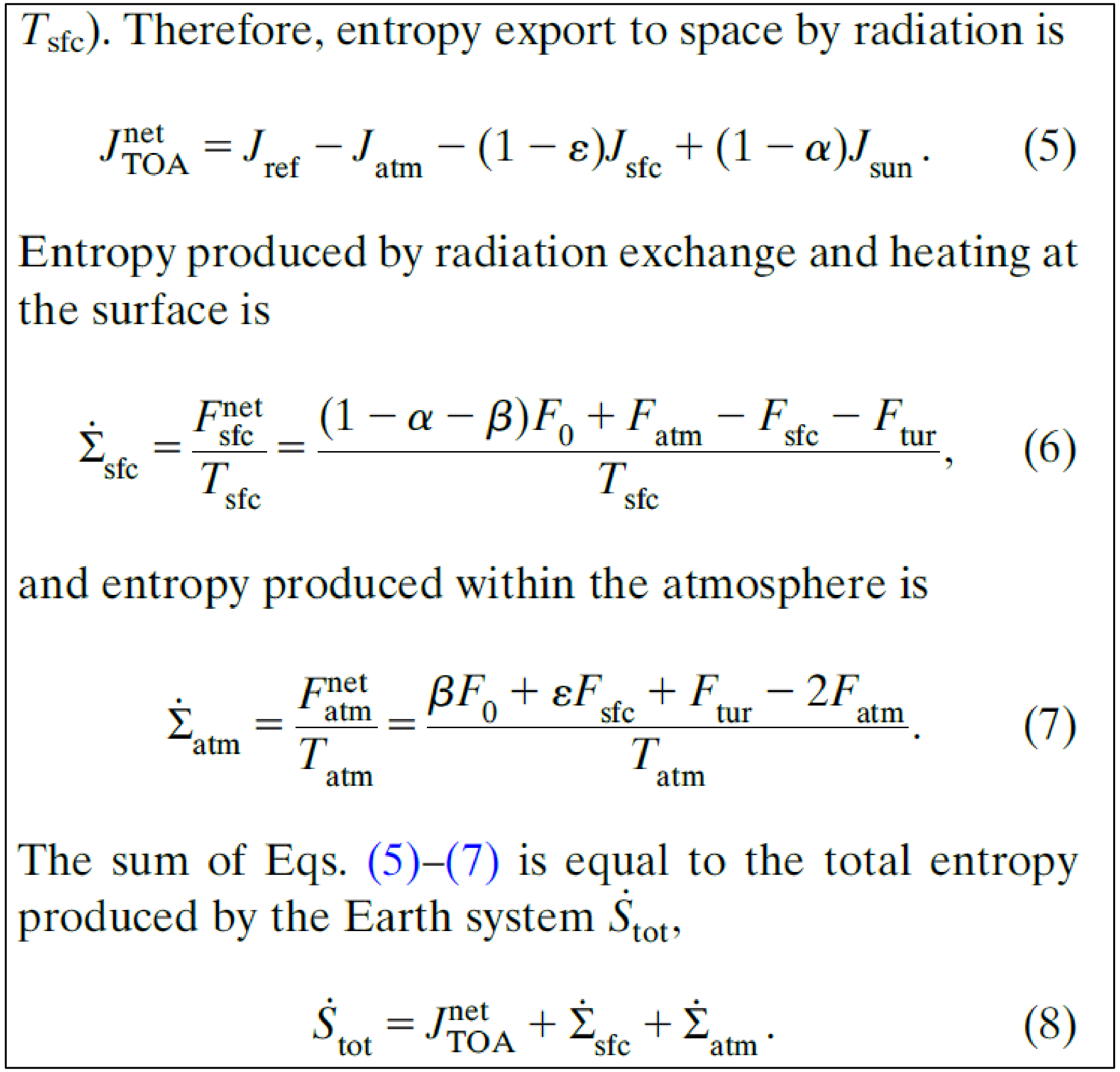
Eq. (2) $A = 2A_0$

Eq. (2): Why ε = 1? Maximum entropy production?



Kato and Rose (2020, Fig. 1)

Entropy export to space by radiation (Eq.5), entropy produced within the atmosphere (Eq.7), and the total entropy produced by the Earth system (Eq.8), as a function of *ε*, is at maximum if *ε* = 1.



T_{sfc}). Therefore, entropy export to space by radiation is

$$J^{net}_{TOA} = J_{ref} - J_{atm} - (1-\varepsilon)J_{sfc} + (1-\alpha)J_{sun}. \qquad (5)$$

Entropy produced by radiation exchange and heating at the surface is

$$\dot{\Sigma}_{sfc} = \frac{F^{net}_{sfc}}{T_{sfc}} = \frac{(1-\alpha-\beta)F_0 + F_{atm} - F_{sfc} - F_{tur}}{T_{sfc}}, \qquad (6)$$

and entropy produced within the atmosphere is

$$\dot{\Sigma}_{atm} = \frac{F^{net}_{atm}}{T_{atm}} = \frac{\beta F_0 + \varepsilon F_{sfc} + F_{tur} - 2F_{atm}}{T_{atm}}. \qquad (7)$$

The sum of Eqs. (5)–(7) is equal to the total entropy produced by the Earth system $\dot{S}_{tot}$,

$$\dot{S}_{tot} = J^{net}_{TOA} + \dot{\Sigma}_{sfc} + \dot{\Sigma}_{atm}. \qquad (8)$$

Eq. (1) SFC SW+LW Net (clear) $= A – E = A_0/2$
Eq. (2) SFC SW+LW Total (clear) $= A = 2A_0$

Creating the all-sky versions (including LWCRE):

Eq. (3) SFC SW+LW Net (all) $= A – E = (A_0 – L)/2$
Eq. (4) SFC SW+LW Total (all) $= A = 2A_0 + L$

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

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

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

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

Four Equations, EBAF Edition 2.8

(March 2000 – Feb 2016) (Rose et al. 2017, 27th CERES STM)

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

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

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

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

Four Equations, EBAF Edition 2.8

(March 2000 – Feb 2016) (Rose et al. 2017, 27th CERES STM)

Eq. (1) SFC SW down – SW up + LW down – LW up (clear) = TOA LW (clear)/2 Diff
Ed2.8 244.06 – 29.74 + 316.27 – 398.40 = 265.59 /2 –0.60

Eq. (2) SFC SW down – SW up + LW down (clear) = 2 × TOA LW (clear)
Ed2.8 244.06 – 29.74 + 316.27 = 2 × 265.59 –0.59

Eq. (3) SFC SW down – SW up + LW down – LW up (all) = [TOA LW (all) – LWCRE]/2
Ed2.8 186.47 – 24.13 + 345.15 – 398.27 = (239.60 – 25.99)/2 +2.41

Eq. (4) SFC SW down – SW up + LW down (all) = 2 × TOA LW (all) + LWCRE
Ed2.8 186.47 – 24.13 + 345.15 = 2 × 239.60 + 25.99 +2.30

Four Equations, EBAF Edition 4.1

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

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

Ed4.1 240.8680 – 29.0724 + 317.4049 – 398.5211 = 266.0122 /2 –2.3267

} –2.5752

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

Ed4.1 240.8680 – 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

Ed4.1 186.8544 – 23.1629 + 345.0108 – 398.7454 = (240.2450 – 25.7672)/2 +2.7083

} +2.5766

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

Ed4.1 186.8544 – 23.1629 + 345.0108 = 2 × 240.2450 + 25.7672 +2.4450

Ed4.1 Mean +0.0007

The four equations are intimately connected

Decrease TOA LW(clear) by 1 Wm^{-2}

Eq. (1)	**SFC**	**SW down – SW up + LW down – LW up**	**(clear)**	**= TOA LW (clear)/2**	**Diff**	
Ed4.1		**240.8680 – 29.0724 + 317.4049 – 398.5211**		**= 266.0122 /2**	**–2.3267**	
Ed4.1		**240.8680 – 29.0724 + 317.4049 – 398.5211**		**= 265.0122 /2**	**–1.8267**	**–2.5752**
Eq. (2)	**SFC**	**SW down – SW up + LW down**	**(clear)**	**= 2 × TOA LW (clear)**		**–1.3252**
Ed4.1		**240.8680 – 29.0724 + 317.4049**		**= 2 × 266.0122**	**–2.8238**	
Ed4.1		**240.8680 – 29.0724 + 317.4049**		**= 2 × 265.0122**	**–0.8238**	
Eq. (3)	**SFC**	**SW down – SW up + LW down – LW up**	**(all)**	**= [TOA LW (all) – LWCRE]/2**		
Ed4.1		**186.8544 – 23.1629 + 345.0108 – 398.7454**		**= (240.2450 – 25.7672)/2**	**+2.7083**	
Ed4.1		**186.8544 – 23.1629 + 345.0108 – 398.7454**		**= (240.2450 – 24.7672)/2**	**+2.2083**	**+2.5766**
Eq. (4)	**SFC**	**SW down – SW up + LW down**	**(all)**	**= 2 × TOA LW (all) + LWCRE**		**+2.8266**
Ed4.1		**186.8544 – 23.1629 + 345.0108**		**= 2 × 240.2450 + 25.7672**	**+2.4450**	
Ed4.1		**186.8544 – 23.1629 + 345.0108**		**= 2 × 240.2450 + 24.7672**	**+3.4450**	
Ed4.1				**Mean**	**+0.0007**	
Ed4.1				**Mean**	**+0.7507**	

Four Equations, EBAF Edition 4.1 & 4.2

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

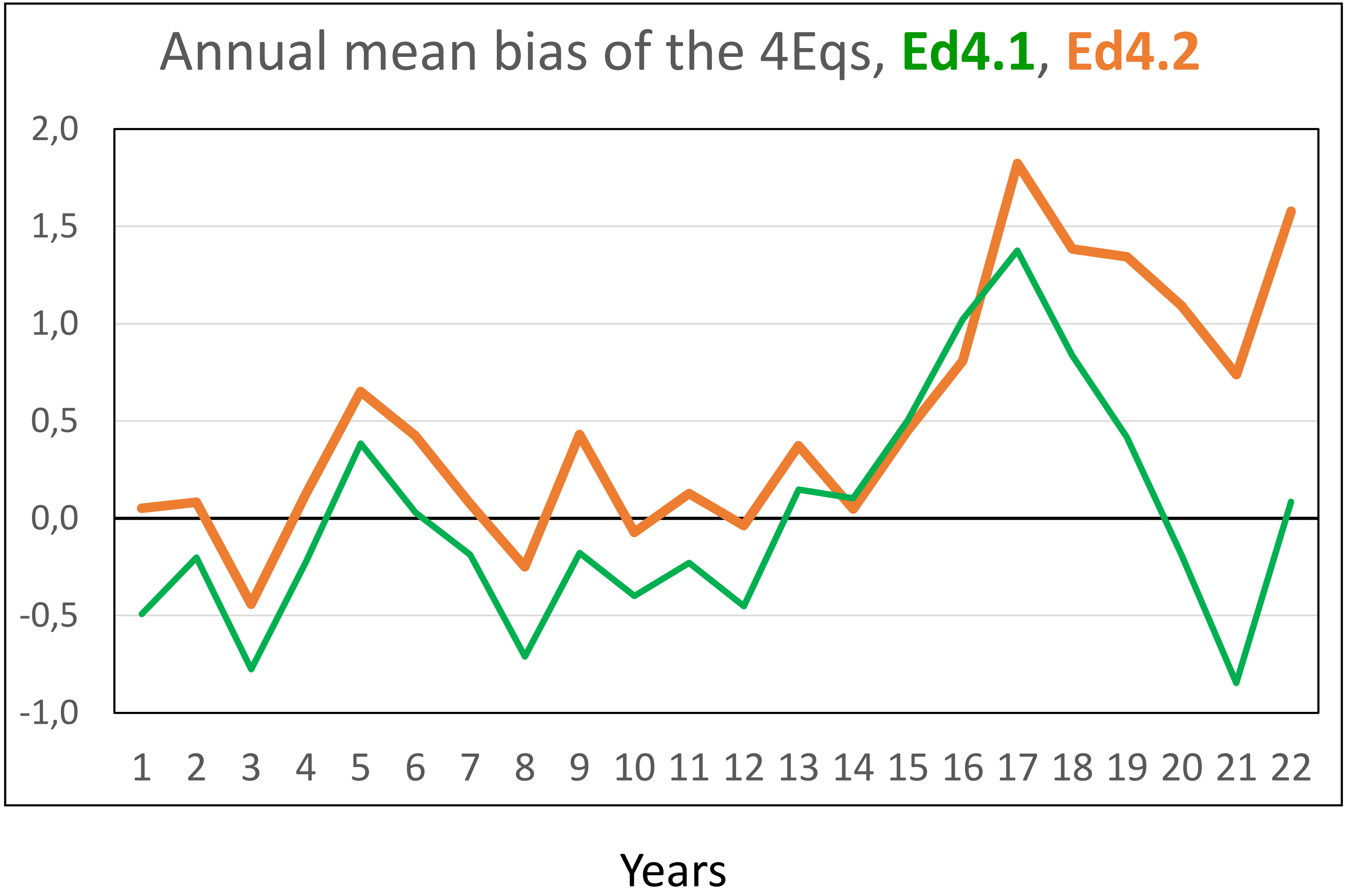
Eq. (1)	**SFC**	**SW down – SW up + LW down – LW up**	**(clear)**	**= TOA LW (clear)/2**	**Diff**	
Ed4.1		**240.8680 – 29.0724 + 317.4049 – 398.5211**		**= 266.0122 /2**	**–2.3267**	
Ed4.2		**241.1519 – 29.7397 + 317.8570 – 398.6099**		**= 266.1348 /2**	**–2.4081**	
Eq. (2)	**SFC**	**SW down – SW up + LW down**	**(clear)**	**= 2 × TOA LW (clear)**		**–2.7043**
Ed4.1		**240.8680 – 29.0724 + 317.4049**		**= 2 × 266.0122**	**–2.8238**	
Ed4.2		**241.1519 – 29.7397 + 317.8570**		**= 2 × 266.1348**	**–3.0005**	
Eq. (3)	**SFC**	**SW down – SW up + LW down – LW up**	**(all)**	**= [TOA LW (all) – LWCRE]/2**		
Ed4.1		**186.8544 – 23.1629 + 345.0108 – 398.7454**		**= (240.2450 – 25.7672)/2**	**+2.7083**	
Ed4.2		**187.0918 – 23.4436 + 346.1147 – 398.4220**		**= (240.3317 – 25.8032)/2**	**+4.0766**	
Eq. (4)	**SFC**	**SW down – SW up + LW down**	**(all)**	**= 2 × TOA LW (all) + LWCRE**		**+3.6865**
Ed4.1		**186.8544 – 23.1629 + 345.0108**		**= 2 × 240.2450 + 25.7672**	**+2.4450**	
Ed4.2		**187.0918 – 23.4436 + 346.1147**		**= 2 × 240.3317 + 25.8032**	**+3.2963**	
Ed4.1				**Mean**	**+0.0007**	
Ed4.2				**Mean**	**+0.4911**	

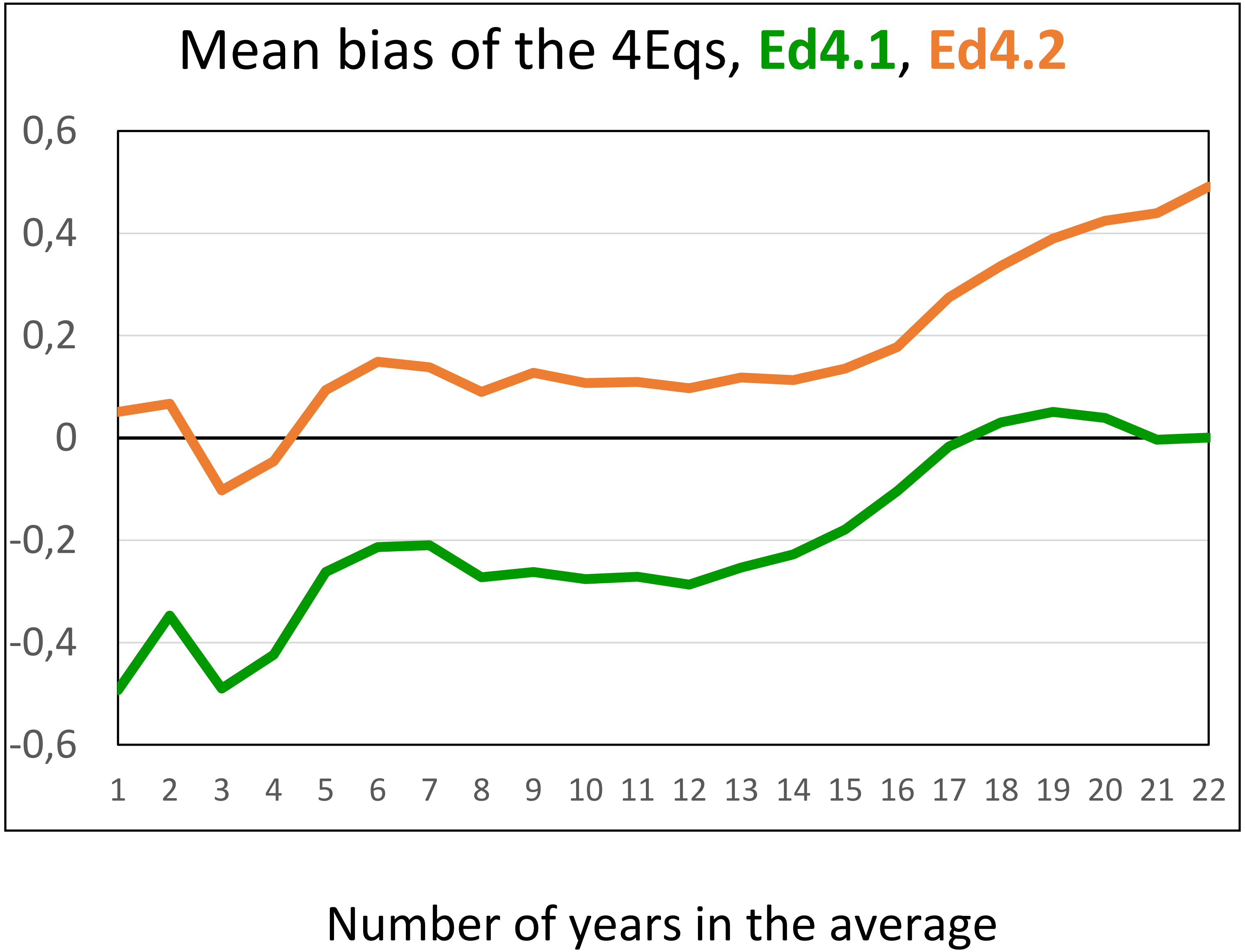
Bias, or Ed4.2 captured something physical that Ed4.1 missed?

EBAF Edition 4.2

22 years (Apr 2000 – Mar 2022)
22 years (Jan 2001 – Dec 2022)

Eq. (1) SFC	**SW down – SW up + LW down – LW up**	**(clear)**	**= TOA LW (clear)/2**	**Diff**	
Apr-March	**241.1519 – 29.7397 + 317.8570 – 398.6099**		**= 266.1348 /2**	**–2.4081**	
Jan-Dec	**241.1085 – 29.7012 + 317.9809 – 398.7213**		**= 266.1207 /2**	**–2.3935**	
Eq. (2) SFC	**SW down – SW up + LW down**	**(clear)**	**= 2 × TOA LW (clear)**		**–2.7043** **–2.6234**
Apr-March	**241.1519 – 29.7397 + 317.8570**		**= 2 × 266.1348**	**–3.0005**	
Jan-Dec	**241.1085 – 29.7012 + 317.9809**		**= 2 × 266.1207**	**–2.8533**	
Eq. (3) SFC	**SW down – SW up + LW down – LW up**	**(all)**	**= [TOA LW (all) – LWCRE]/2**		
Apr-March	**187.0918 – 23.4436 + 346.1147 – 398.4220**		**= (240.3317 – 25.8032)/2**	**+4.0766**	
Jan-Dec	**187.0941 – 23.4179 + 346.2001 – 398.5297**		**= (240.3606 – 25.7601) /2**	**+4.0463**	
Eq. (4) SFC	**SW down – SW up + LW down**	**(all)**	**= 2 × TOA LW (all) + LWCRE**		**+3.6865** **+3.7206**
Apr-March	**187.0918 – 23.4436 + 346.1147**		**= 2 × 240.3317 + 25.8032**	**+3.2963**	
Jan-Dec	**187.0941 – 23.4179 + 346.2001**		**= 2 × 240.3606 + 25.7601**	**+3.3949**	
Apr-March			**Mean**	**+0.4911**	
Jan-Dec			**Mean**	**+0.5486**	


Annual mean bias of the 4Eqs, Ed4.1, Ed4.2
2,0
1,5
1,0
0,5
0,0
-0,5
-1,0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Years


Mean bias of the 4Eqs, Ed4.1, Ed4.2
0,6
0,4
0,2
0
-0,2
-0,4
-0,6
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Number of years in the average

Libera Science Goals & Objectives

Overarching goals:

1) Provide seamless continuity of the ERB measurement with characteristics identical to CERES

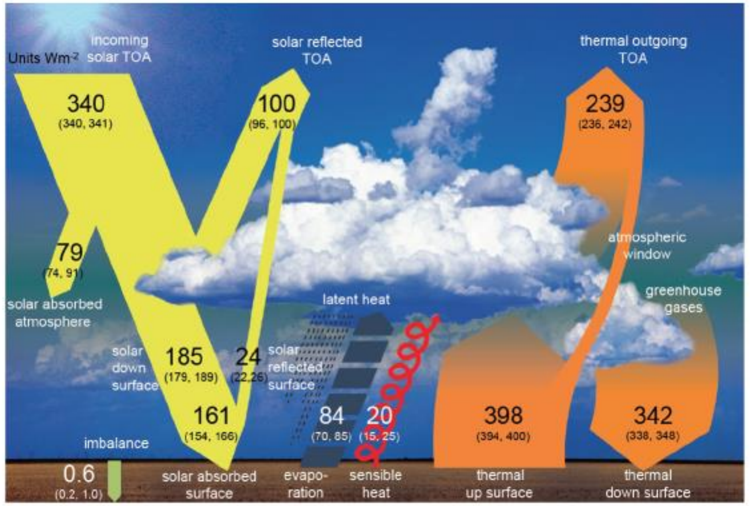
- ➢ Prevents gap in ERB data record critical for studies of global climate change
- ➢ Tied to **Science objective 1**: Use extended record to identify and quantify processes responsible for the instantaneous to decadal variability of ERB

2) Develop a self-contained, innovative, affordable observing system

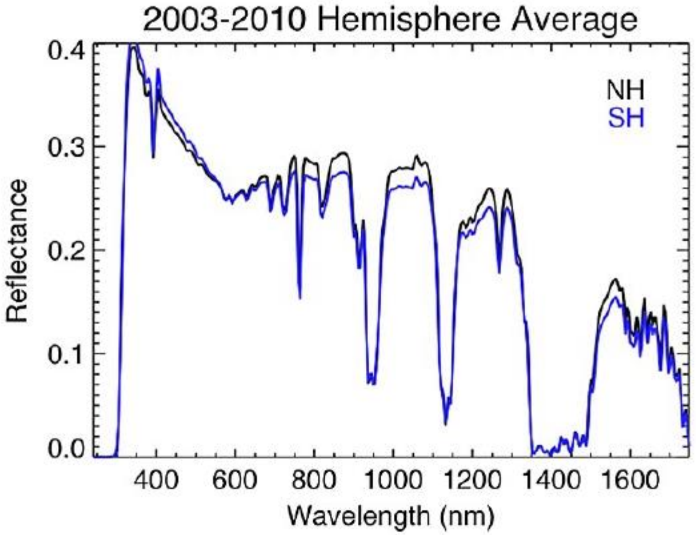
- ➢ Novel, miniaturized detectors greatly improve accuracy & stability and pave way toward smaller & cost-effective follow-on mission.
- ➢ **Science objective 2** *Libera* tests a miniature wide field-of-view camera to provide scene & angular context crucial for radiative flux retrieval

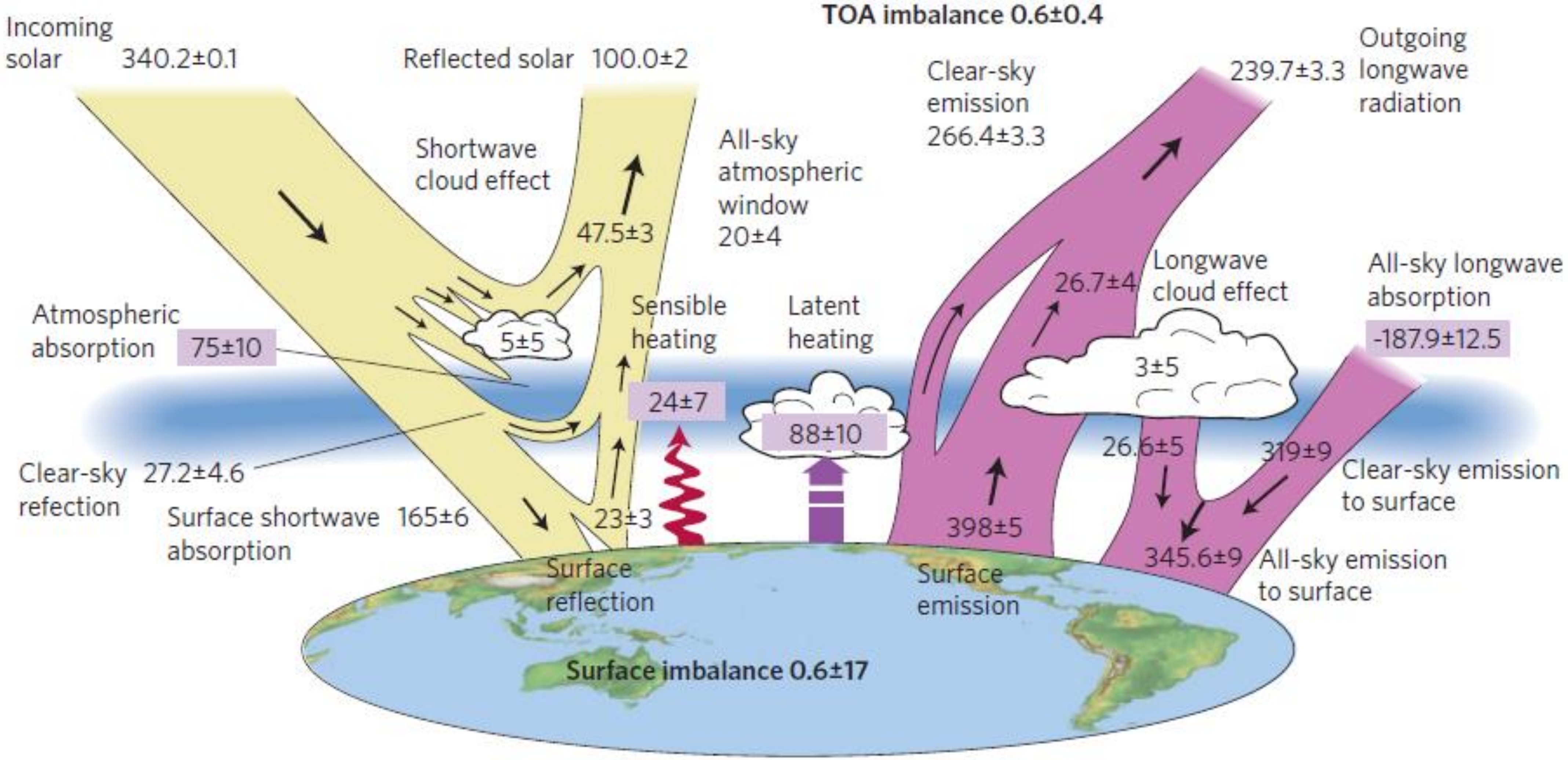
3) Provide new and enhanced capabilities that support extending ERB science goals

- ➢ Employ Split-Shortwave channel to derive SW VIS and NIR fluxes and quantify SW energy disposition
- ➢ Tied to **Science objective 3**: Revolutionize understanding of spatio-temporal variations in SW, VIS & NIR irradiance

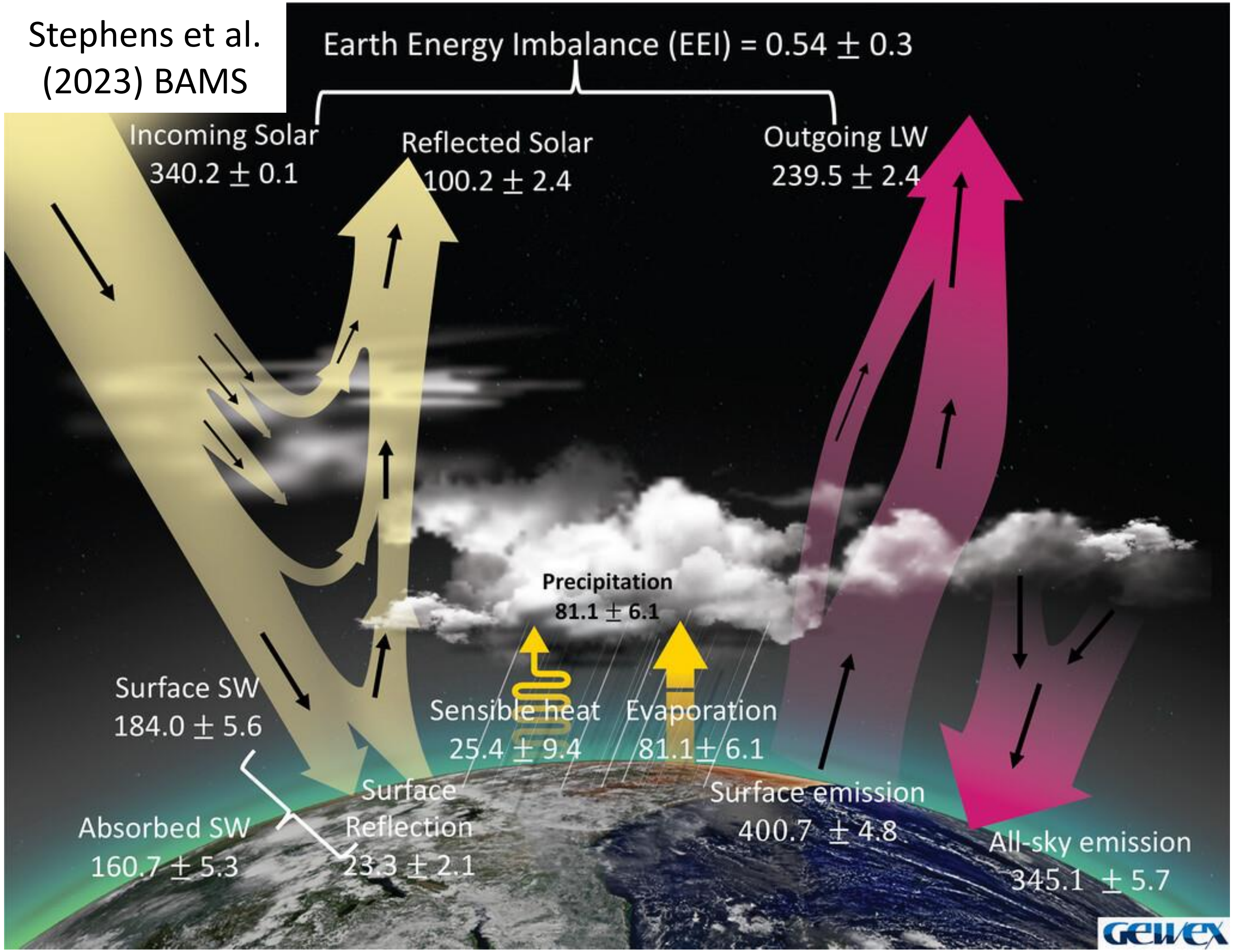


Hemispheric Albedo Symmetry?

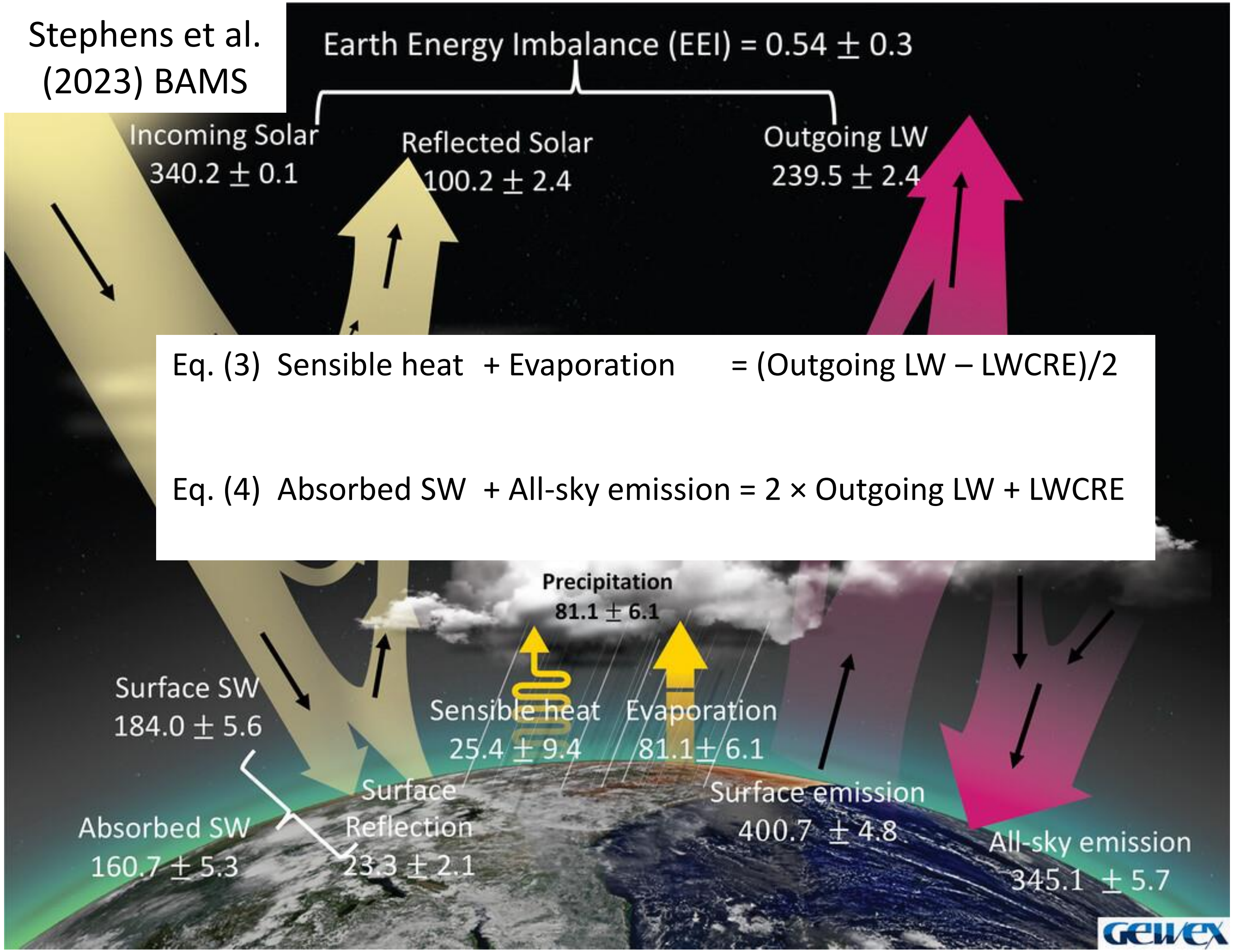



TOA imbalance 0.6±0.4
Incoming solar 340.2±0.1
Reflected solar 100.0±2
Shortwave cloud effect
47.5±3
All-sky atmospheric window 20±4
Clear-sky emission 266.4±3.3
239.7±3.3
Outgoing longwave radiation
Atmospheric absorption
75±10
5±5
Sensible heating
24±7
Latent heating
88±10
26.7±4
Longwave cloud effect
3±5
All-sky longwave absorption
-187.9±12.5
Clear-sky refection 27.2±4.6
Surface shortwave absorption 165±6
23±3
Surface reflection
398±5
Surface emission
26.6±5
319±9
Clear-sky emission to surface
345.6±9
All-sky emission to surface
Surface imbalance 0.6±17

Stephens et al. (2023) BAMS



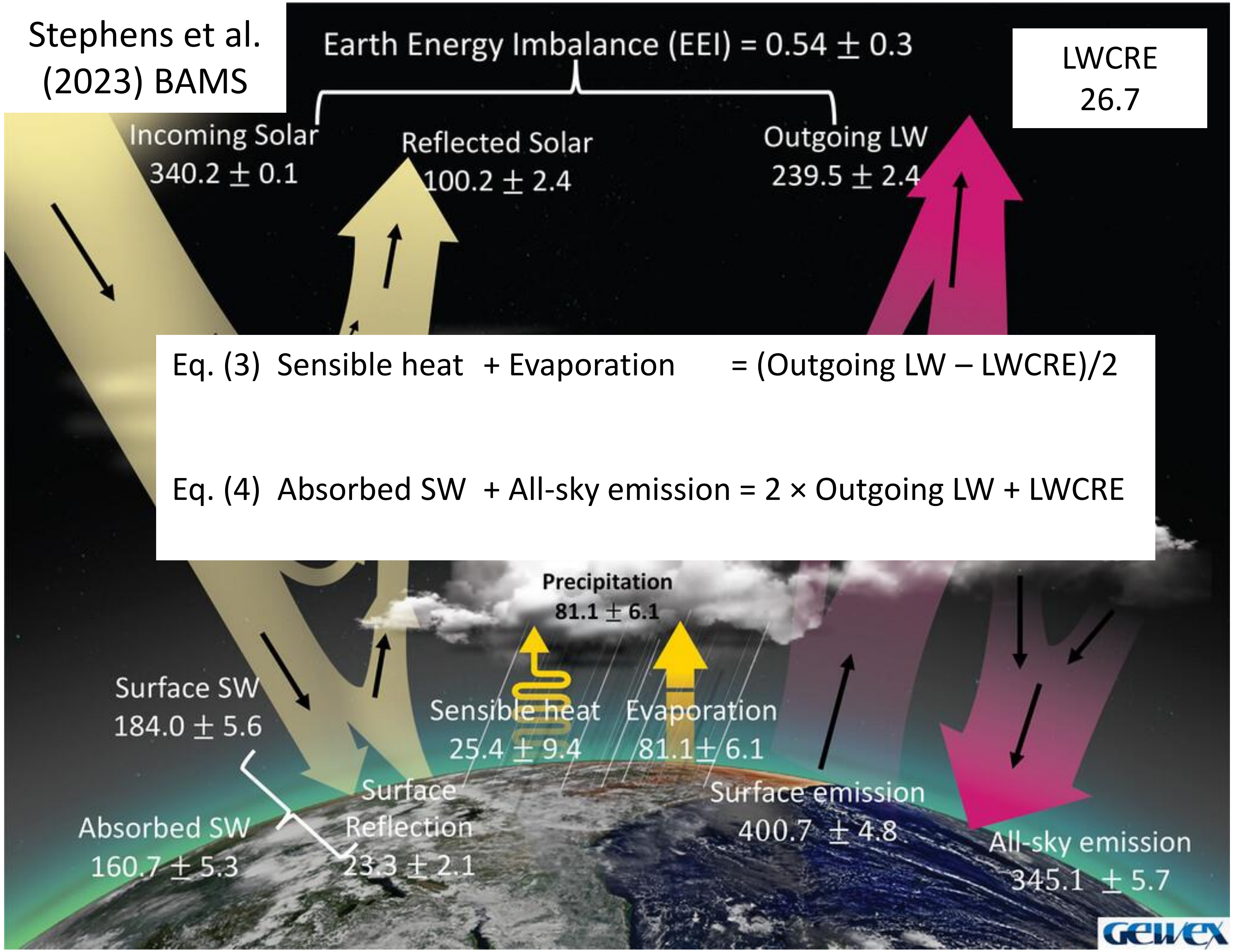
Stephens et al. (2023) BAMS



Eq. (3) Sensible heat + Evaporation = (Outgoing LW – LWCRE)/2

Eq. (4) Absorbed SW + All-sky emission = 2 × Outgoing LW + LWCRE

Stephens et al.
(2023) BAMS



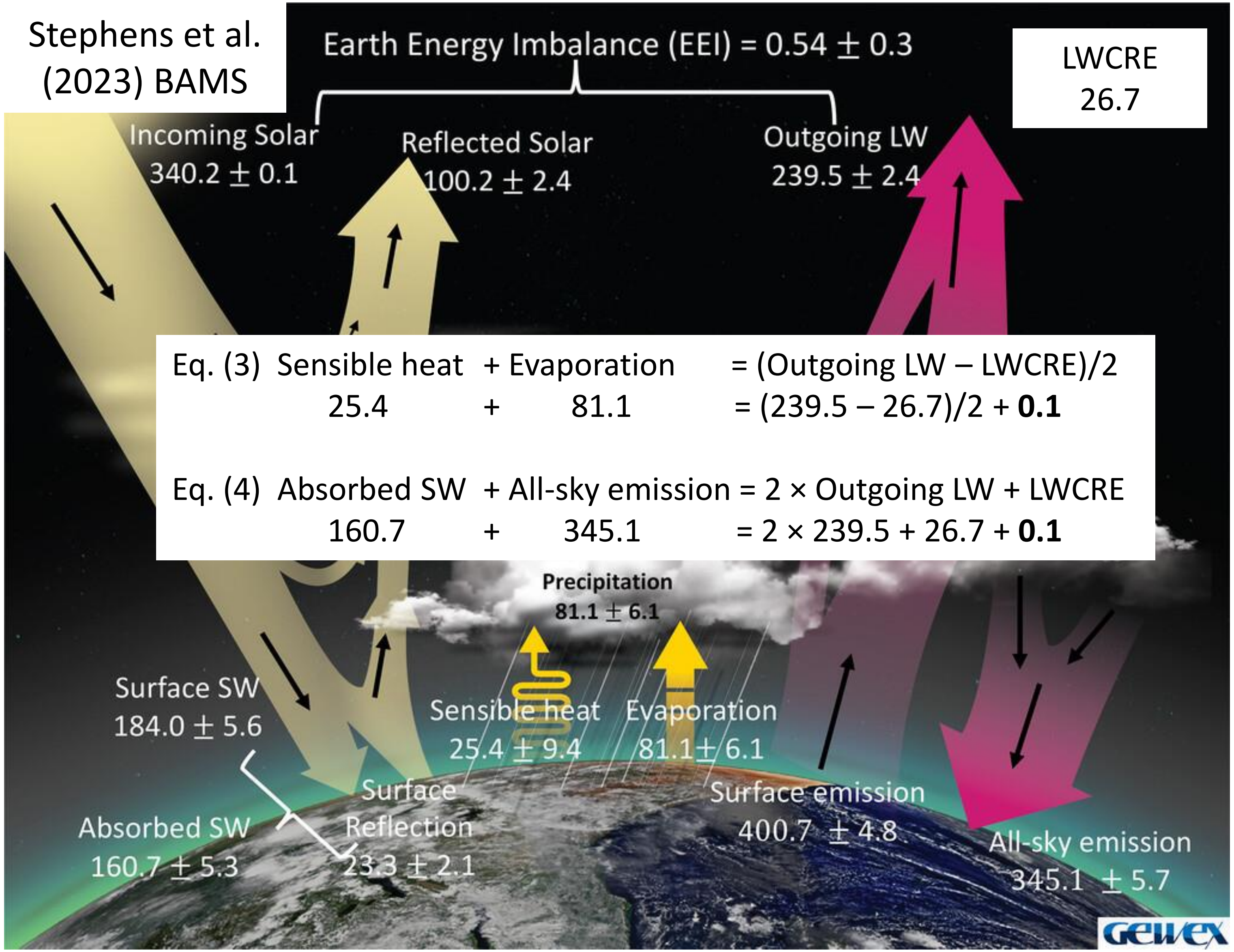
LWCRE
26.7

Eq. (3) Sensible heat + Evaporation = (Outgoing LW – LWCRE)/2

Eq. (4) Absorbed SW + All-sky emission = 2 × Outgoing LW + LWCRE

Stephens et al. 2012

Stephens et al. (2023) BAMS



LWCRE
26.7

Eq. (3) Sensible heat + Evaporation = (Outgoing LW – LWCRE)/2
25.4 + 81.1 = (239.5 – 26.7)/2 + **0.1**

Eq. (4) Absorbed SW + All-sky emission = 2 × Outgoing LW + LWCRE
160.7 + 345.1 = 2 × 239.5 + 26.7 + **0.1**

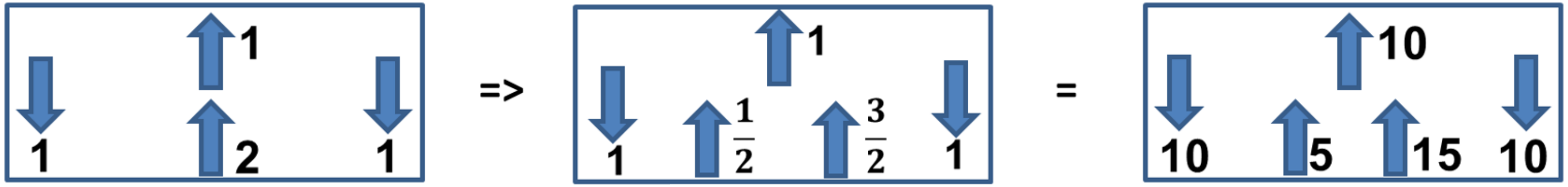
Stephens et al. 2012

Eqs. (3) and (4) express fundamental physical requirements, verified by 30 years of GEWEX.

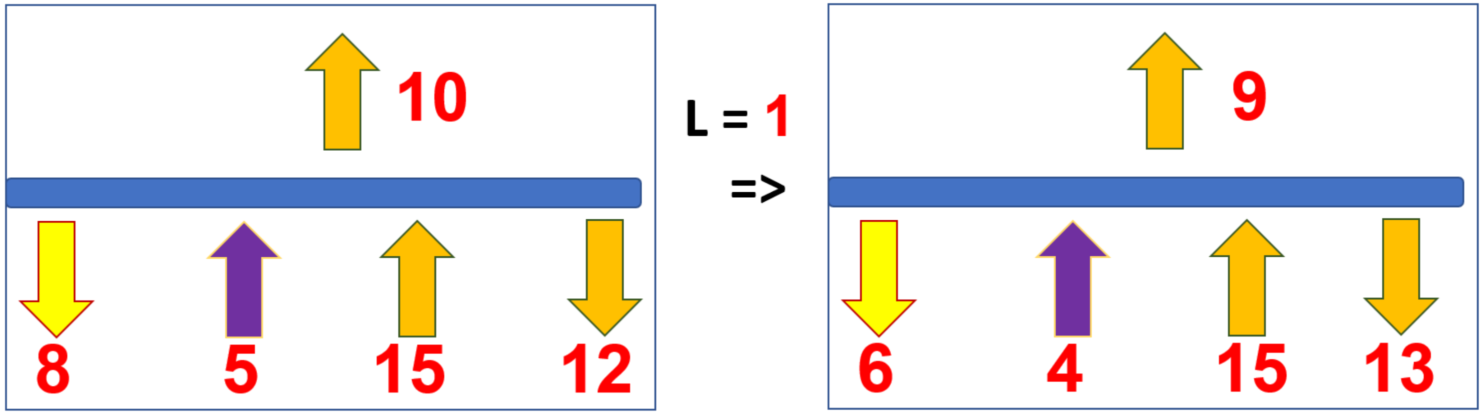
Any future global energy flow estimate, climate report, sensitivity study, water change prediction, cloud forcing and CRE-feedback assessment should strictly satisfy these constraints with this examplary accuracy.

The **N**-numbers, as solution of the equations

Pure geometry, no reference to GHGs



Eq.(2) $A = 2A_0$ (Clear-sky) Eq.(1) $\Delta A = A_0/2$, $E = 3A_0/2$



$8 + 12 - 15 = 10 / 2$

$8 + 12 = 10 \times 2$

Eq. (1) SFC Net = $A_0/2$

Eq. (2) SFC Tot = $2A_0$

Clear-sky

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

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

Eq. (3) SFC Net = $(A_0 - L)/2$

Eq. (4) SFC Tot = $2A_0 + L$

All-sky

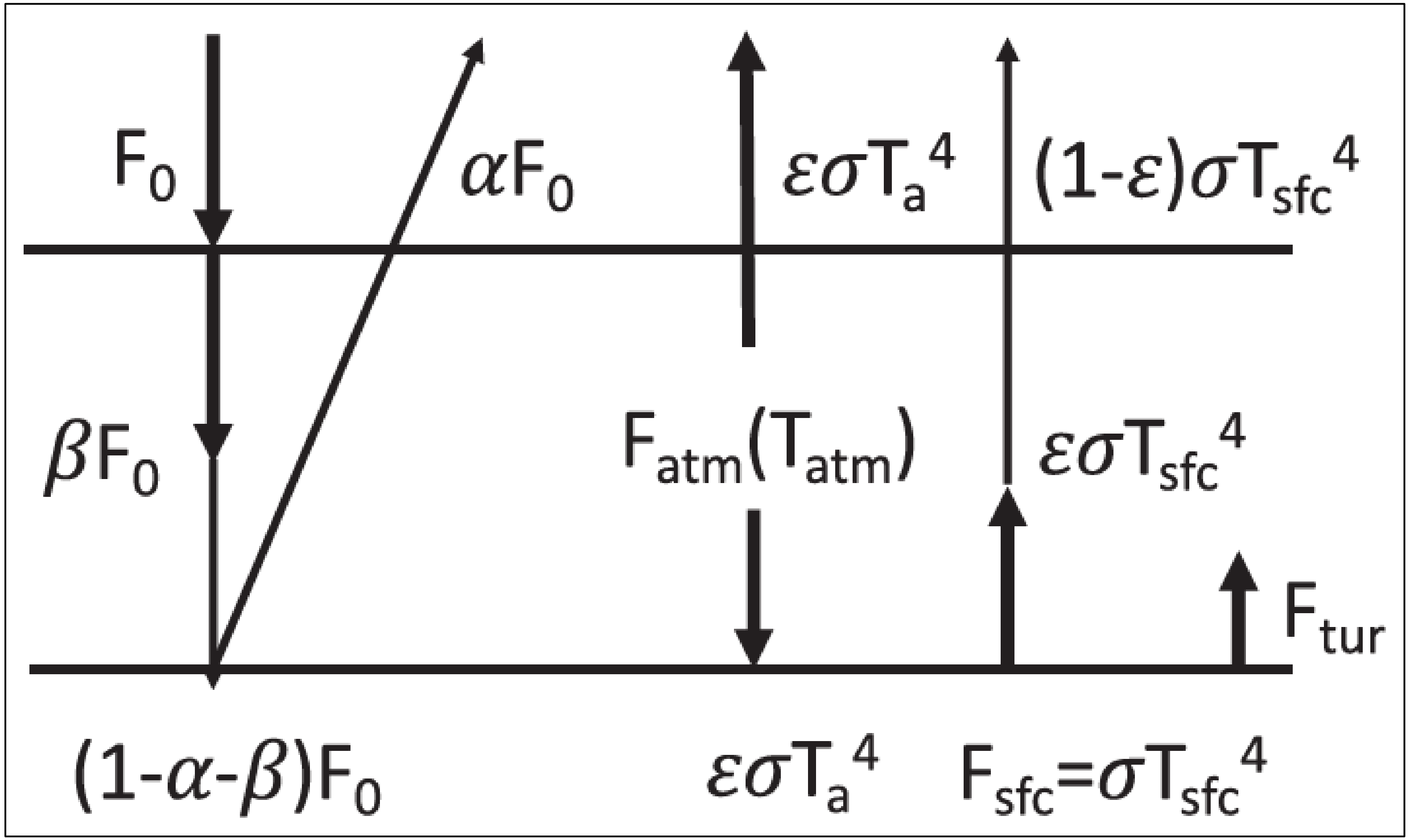
Ed4.2 is better (closer to **N**) in most flux components in the clear-sky

	Clear-sky	**N**	**N × Unit**	**Ed4.1**	**Diff**	**Ed4.2**	**Diff**
TOA	LW	**10**	266.80	266.01	-0.79	266.13	-0.67
Surface	SW Net	**8**	213.44	211.80	-1.64	211.41	-2.03
	LW down	**12**	320.16	317.40	-2.76	317.86	-2.30
	LW up	**15**	400.20	398.52	-1.68	398.61	-1.59
	LW Net	**-3**	-80.04	-81.12	-1.08	-80.75	-0.71
	TOT Net	**5**	133.40	130.68	-2.72	130.66	-2.74

No significant difference, Ed4.1 is a bit better

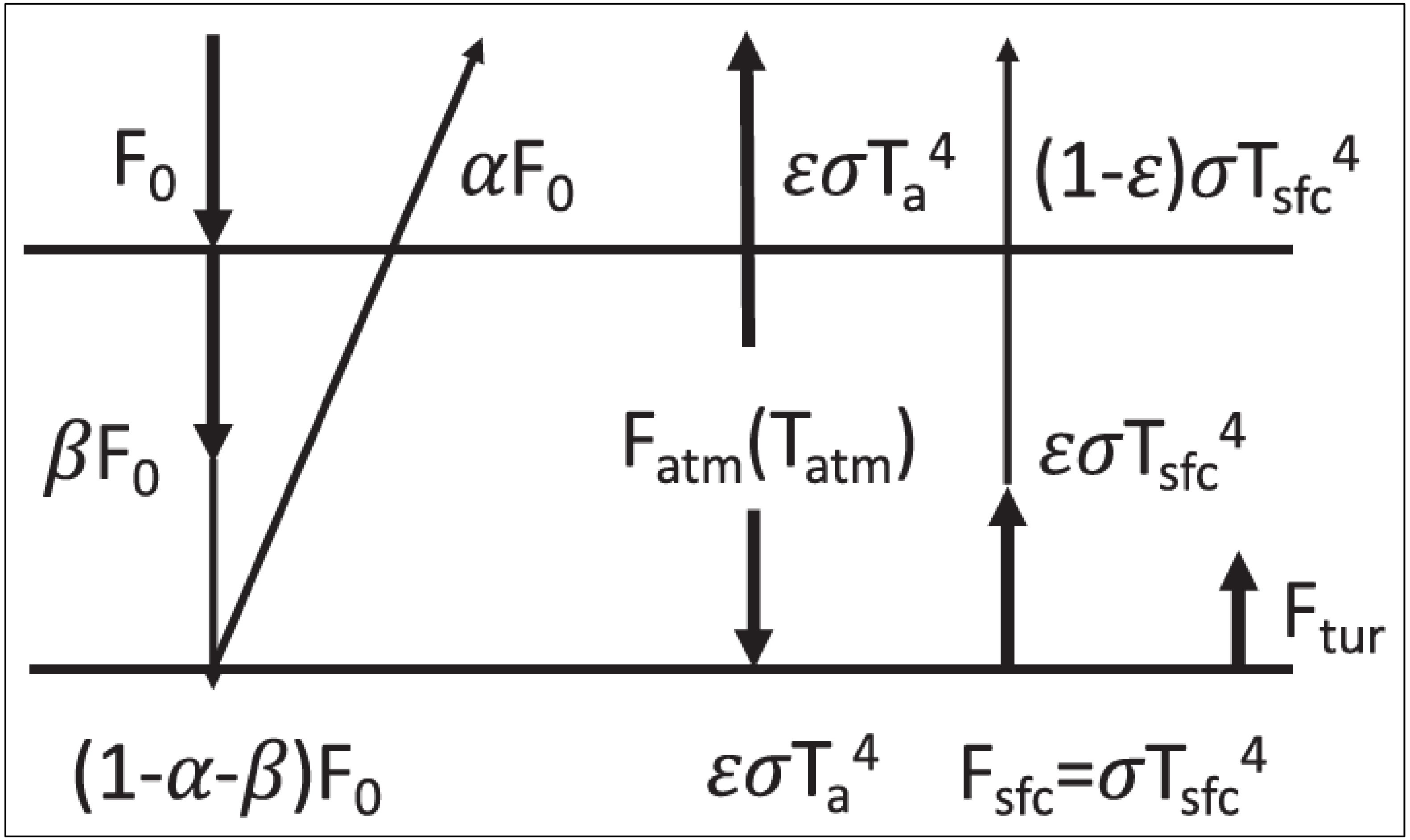
	All-sky	**N**	**N × Unit**	**Ed4.1**	**Diff**	**Ed4.2**	**Diff**
TOA	LW	**9**	240.12	240.25	0.13	240.33	0.21
Surface	SW Net	**6**	160.08	163.69	3.61	163.65	3.57
	LW down	**13**	346.84	345.01	-1.83	346.11	-0.73
	LW up	**15**	400.20	398.75	-1.45	398.42	-1.78
	LW Net	**-2**	-53.36	-53.74	-0.38	-52.31	1.05
	TOT Net	**4**	106.73	109.95	3.22	111.34	4.61
	LW CRE	**1**	26.68	25.77	-0.91	25.80	-0.88

But what about α and β ?



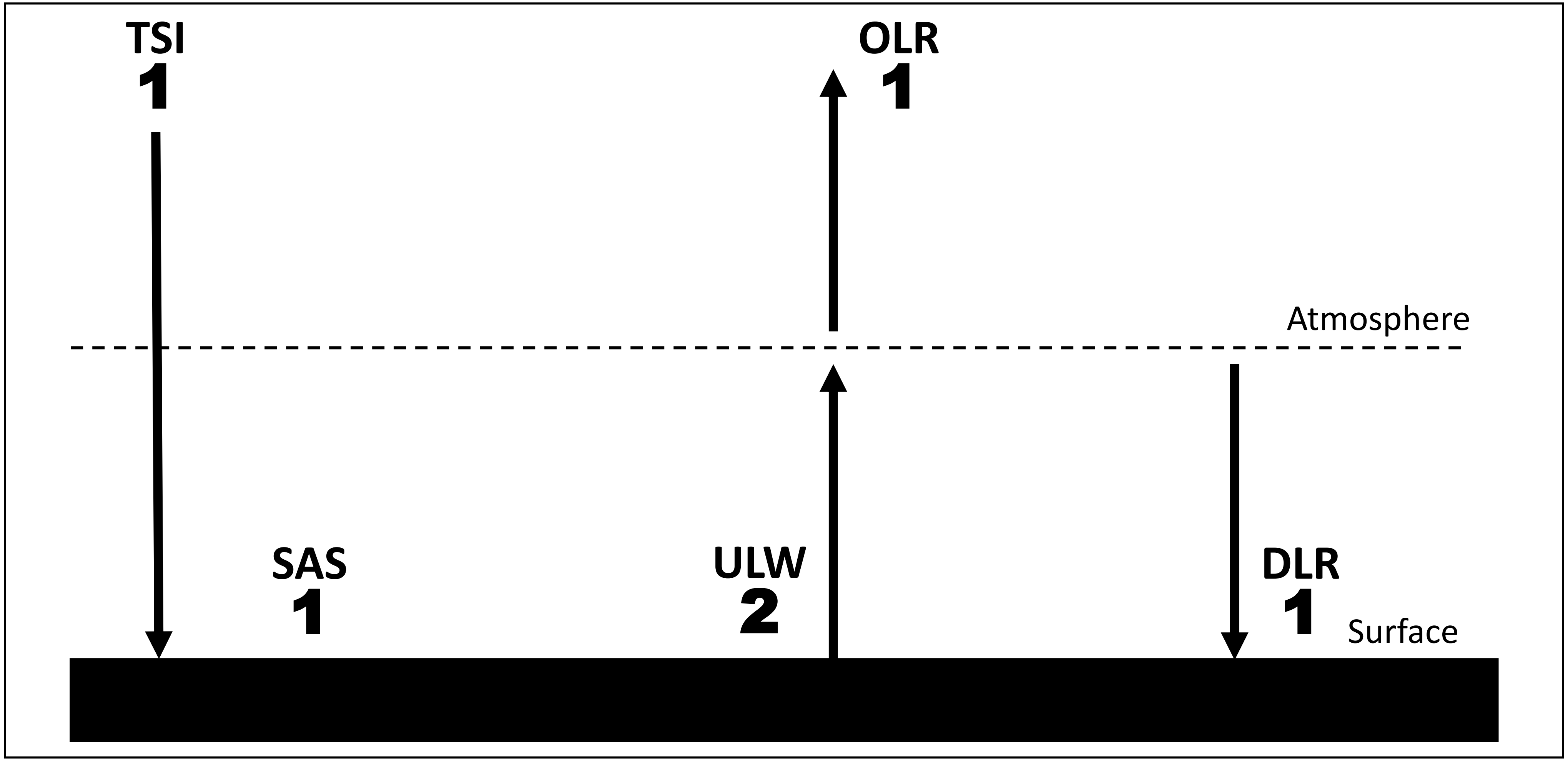
Kato and Rose (2020)

Starting point: The simplest greenhouse model



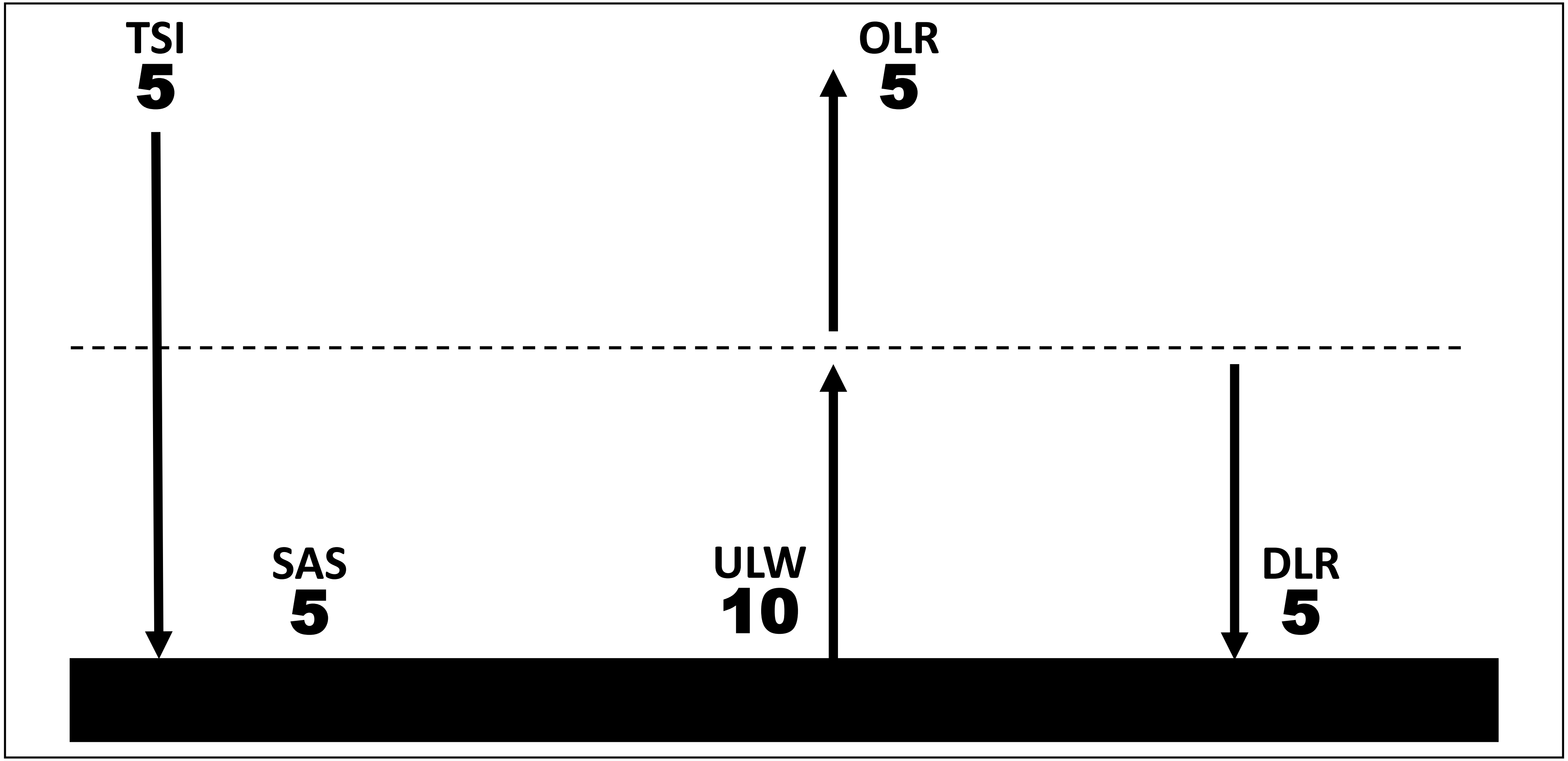
$\alpha = \beta = 0$ $\varepsilon = 1$ $\sigma T_{sfc}^4 = 2\sigma T_a^4$ $F_{tur} = 0$

Starting point: The simplest greenhouse model

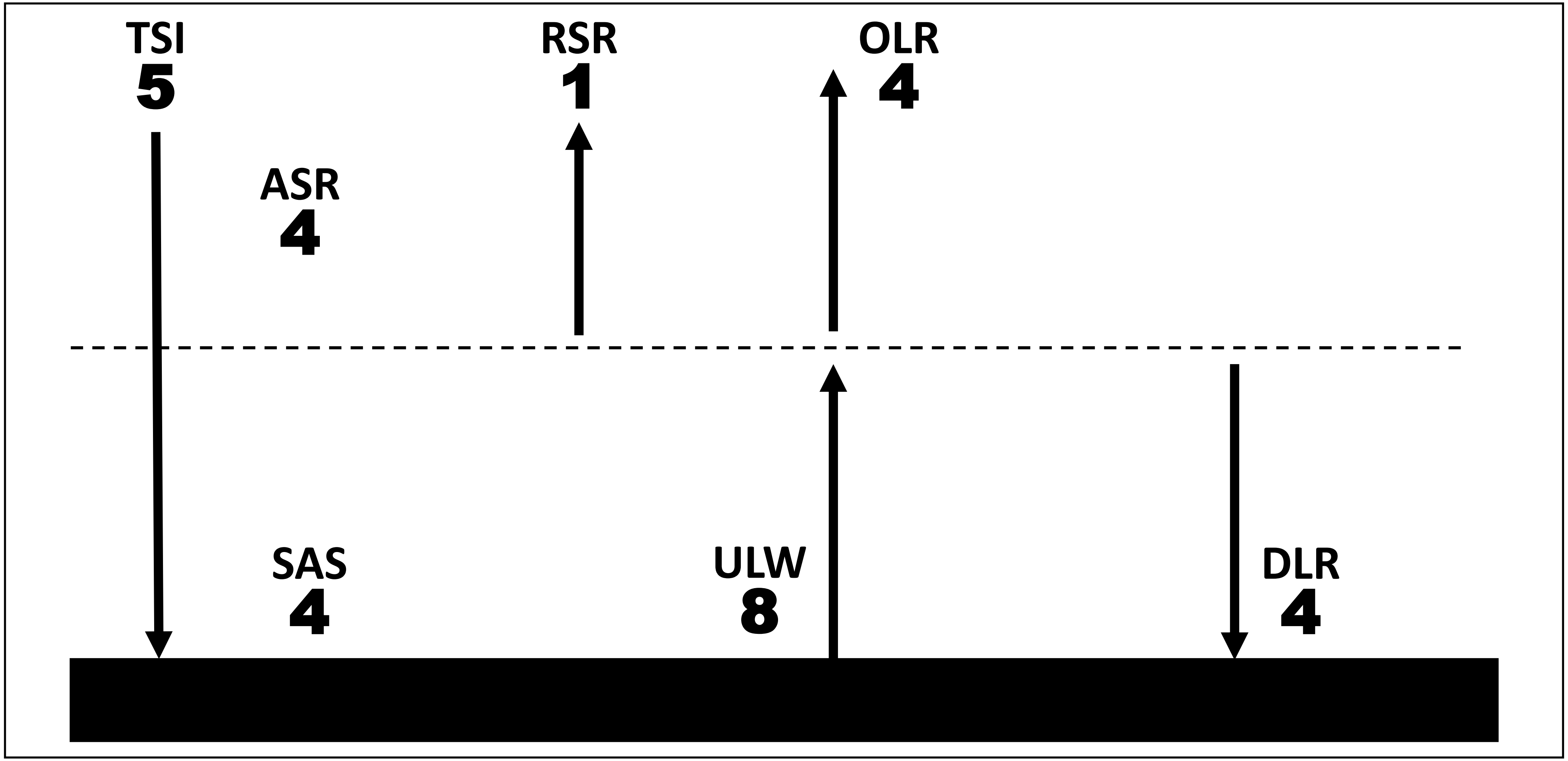


Solar Absorbed Surface (SAS) Upward LongWave (ULW) Downward Longwave Radiation (DLR)

Multiply by 5



Introduce **1** unit RSR at TOA; α = 1/5



TSI
5

RSR
1

OLR
4

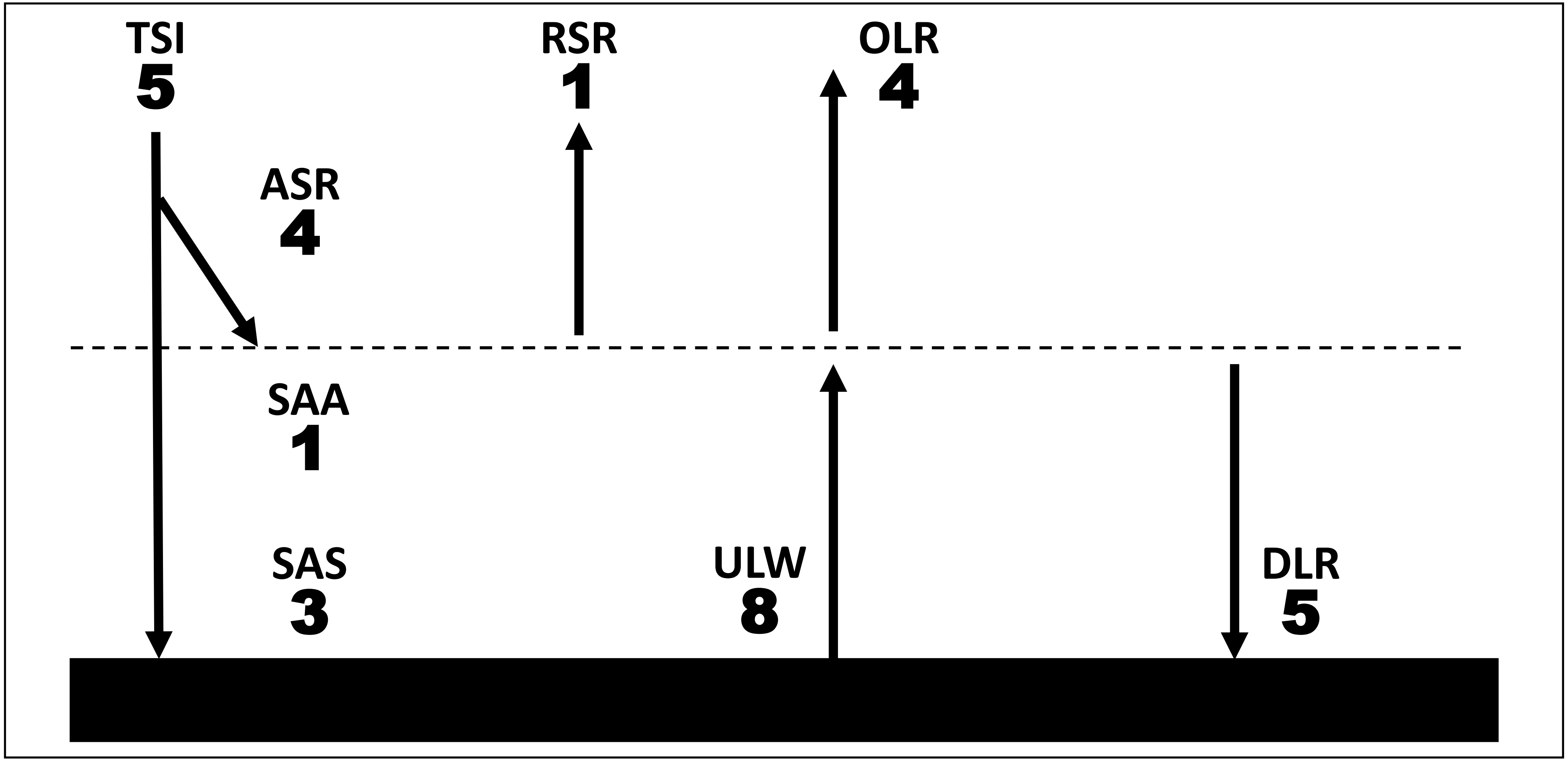
ASR
4

SAS
4

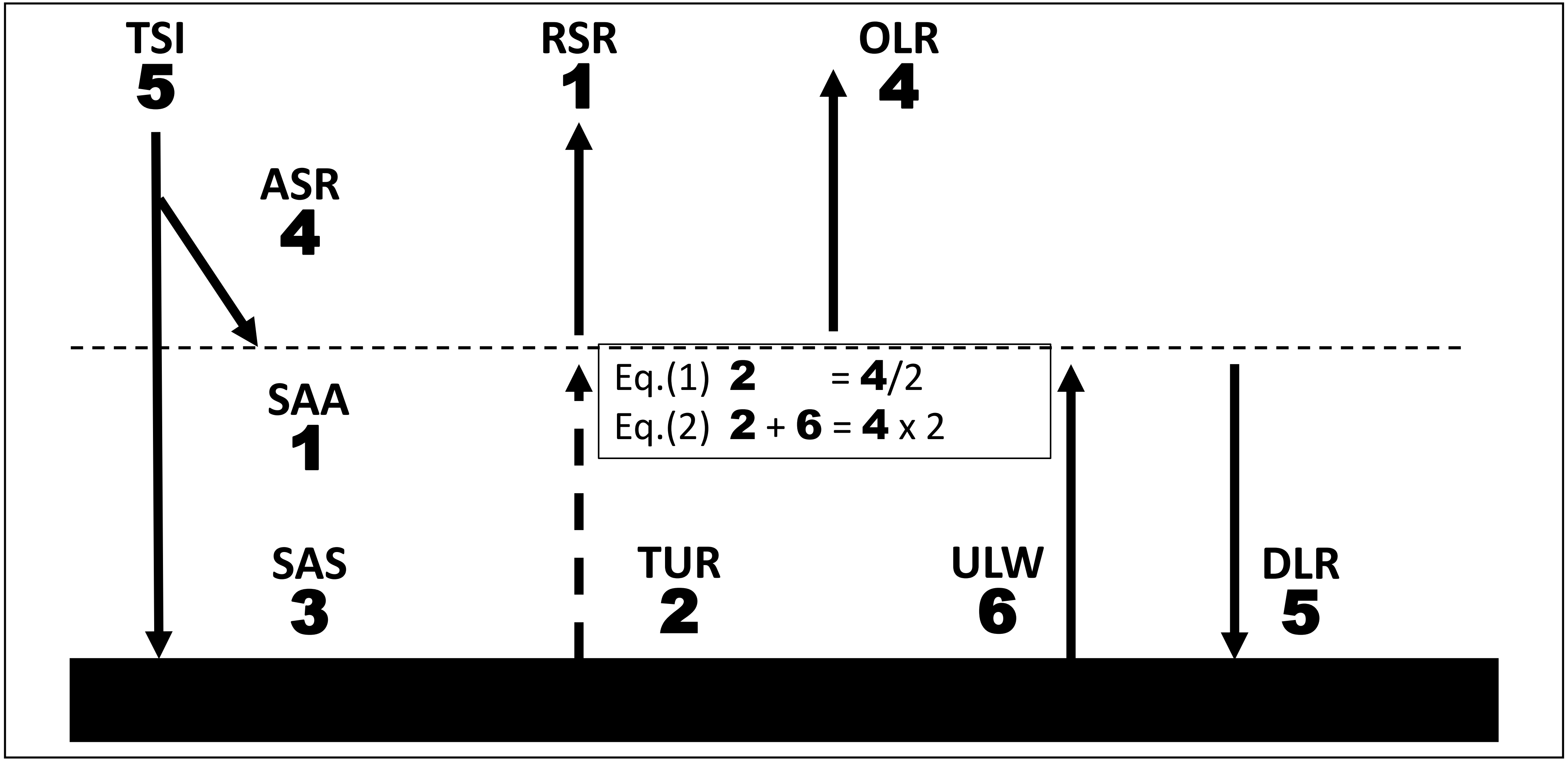
ULW
8

DLR
4

Allow **1** unit solar absorption in atmosphere; β = 1/5

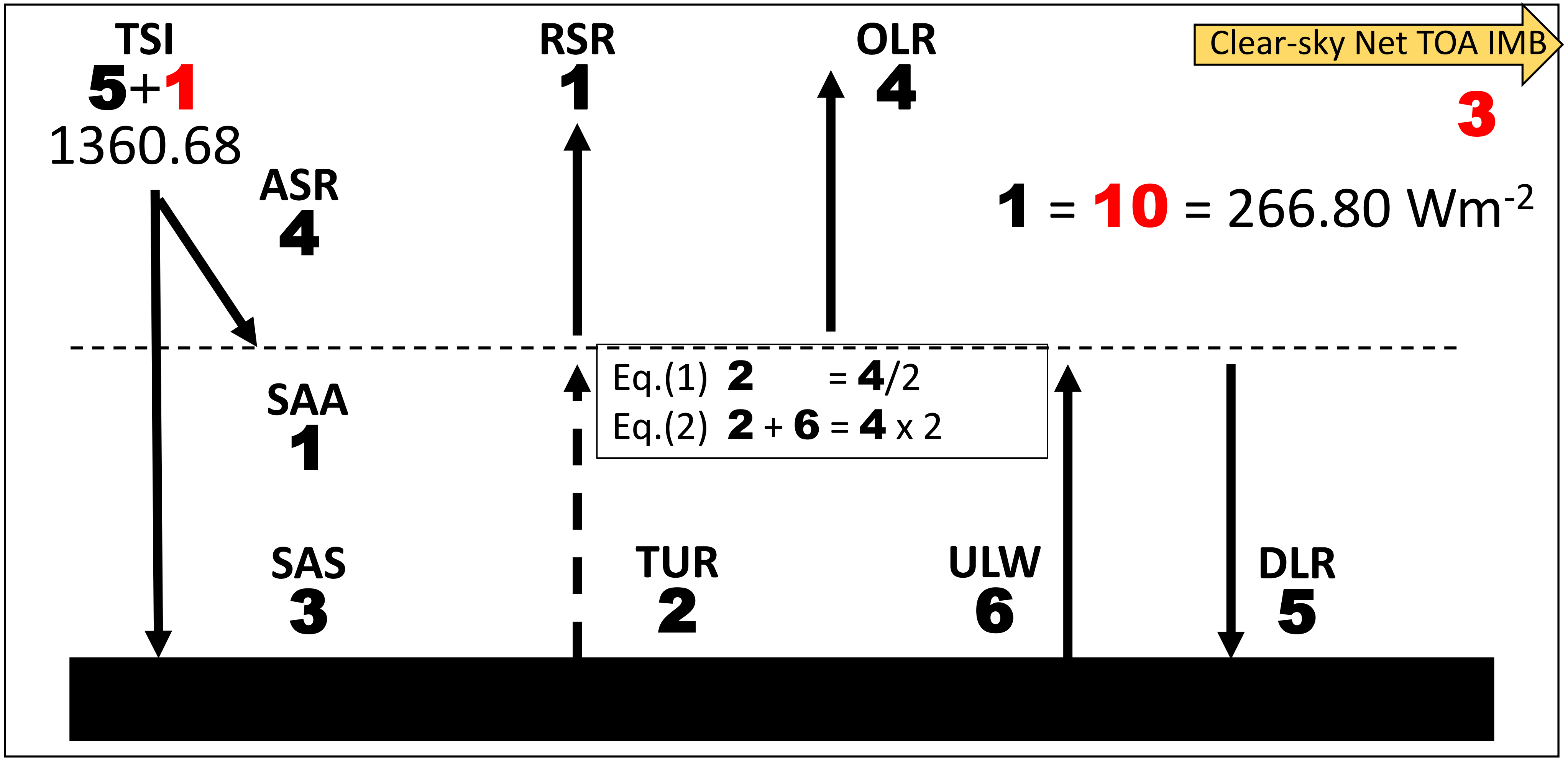


Add **2** units turbulence to satisfy Eqs. (1) and (2)



Eq.(1) **2** = **4**/2
Eq.(2) **2** + **6** = **4** x 2

Calibrate to TSI: 1 (black) unit is 10 (red) units



TSI
5+**1**
1360.68

ASR
4

RSR
1

OLR
4

Clear-sky Net TOA IMB
3

1 = **10** = 266.80 Wm^{-2}

Eq.(1) **2** = **4**/2
Eq.(2) **2** + **6** = **4** x 2

SAA
1

SAS
3

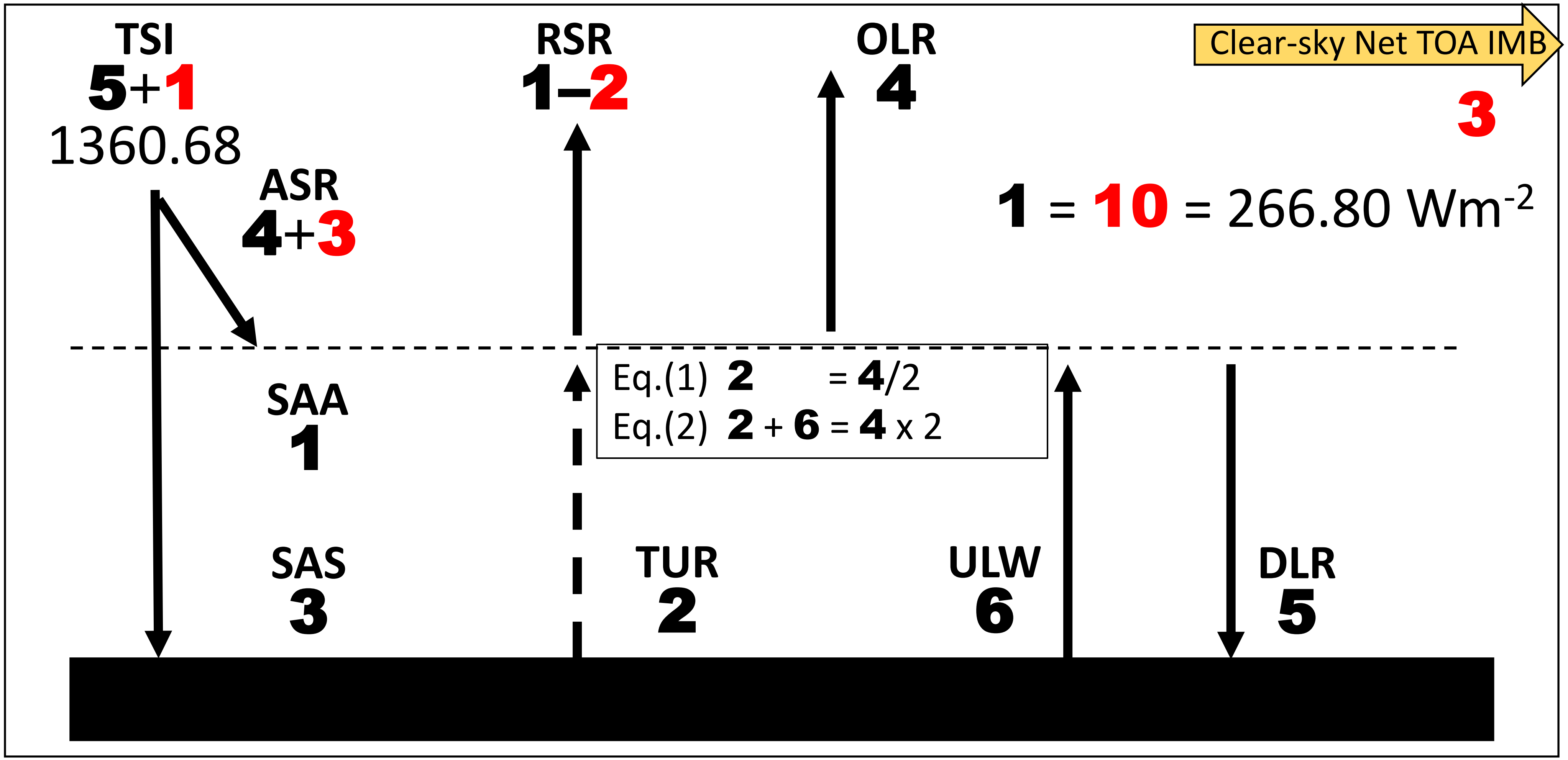
TUR
2

ULW
6

DLR
5

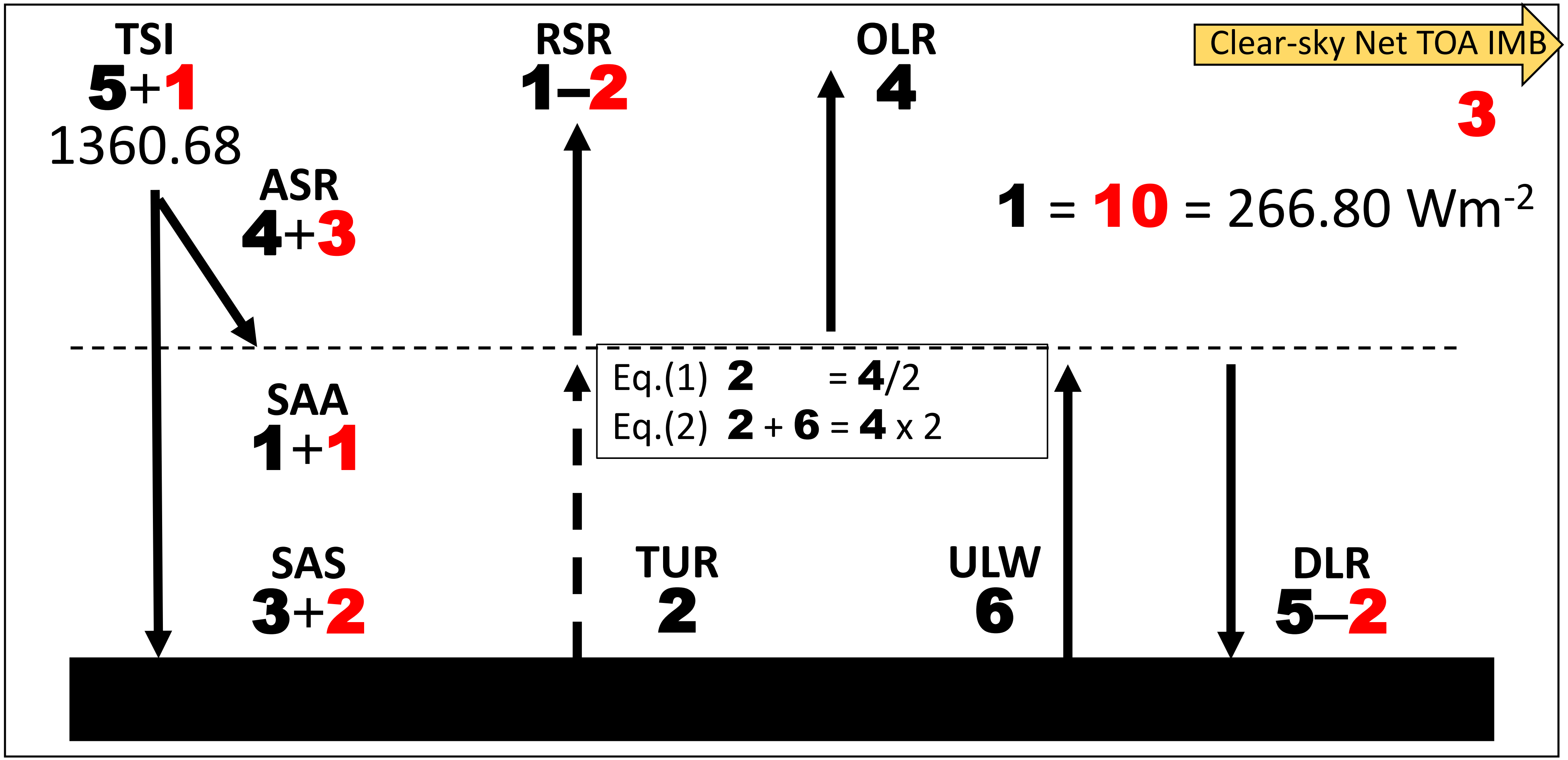
I created 2 (red) units hiatus

Solution: Reflect 2 (red) units less



Absorption will be 3 (red) units more

Re-distribute the absorption: 1 in ATM, 2 at SFC



TSI
5+1
1360.68

RSR
1–2

OLR
4

Clear-sky Net TOA IMB
3

ASR
4+3

1 = 10 = 266.80 Wm^{-2}

Eq.(1) 2 = 4/2
Eq.(2) 2 + 6 = 4 x 2

SAA
1+1

SAS
3+2

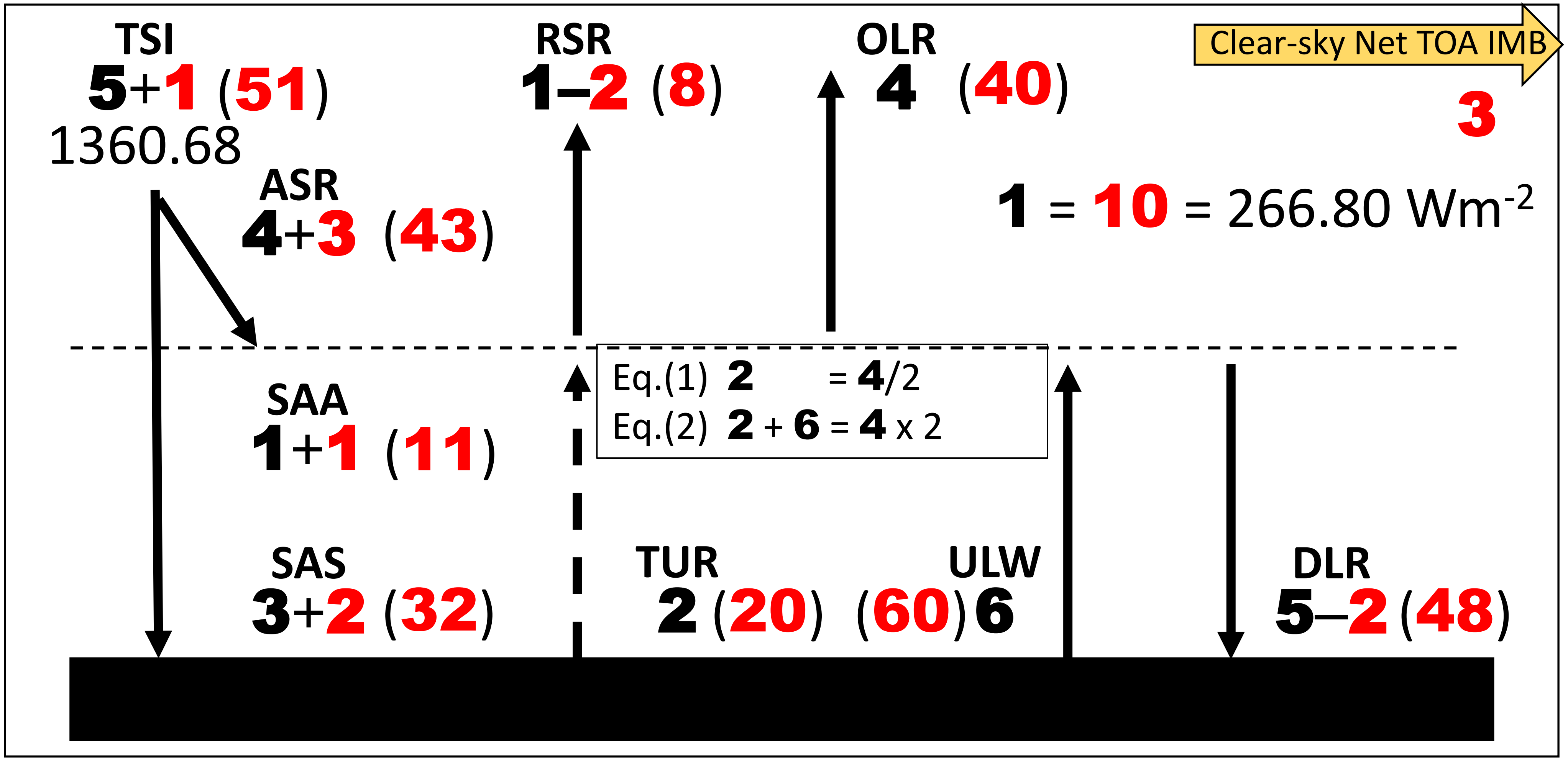
TUR
2

ULW
6

DLR
5–2

Ready. My clear-sky on the disk.

Transform to red units



TSI
5+1 (51)
1360.68

RSR
1–2 (8)

OLR
4 (40)

Clear-sky Net TOA IMB
3

ASR
4+3 (43)

1 = 10 = 266.80 Wm^{-2}

Eq.(1) 2 = 4/2
Eq.(2) 2 + 6 = 4 x 2

SAA
1+1 (11)

SAS
3+2 (32)

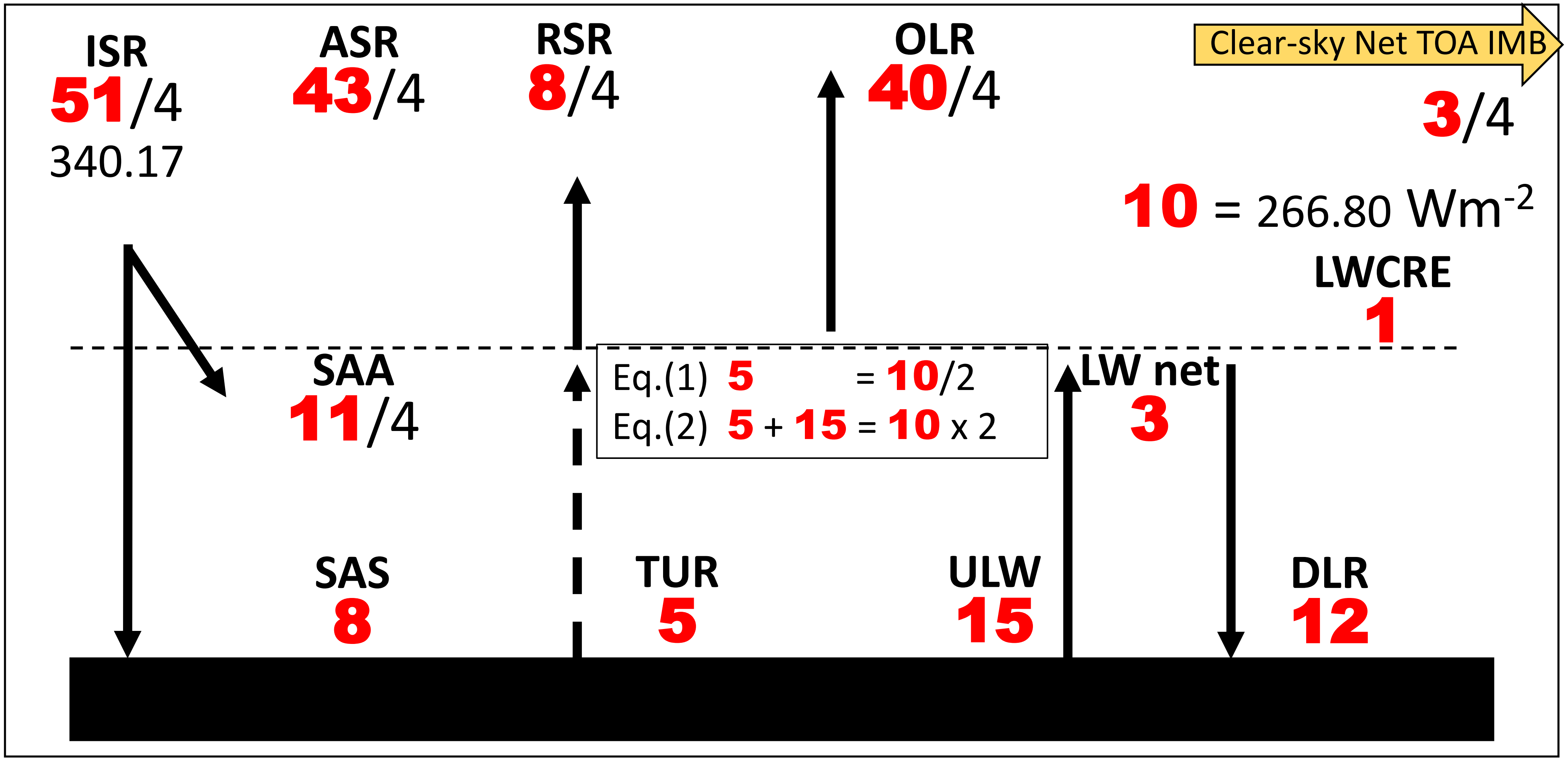
TUR
2 (20)

ULW
(60) 6

DLR
5–2 (48)

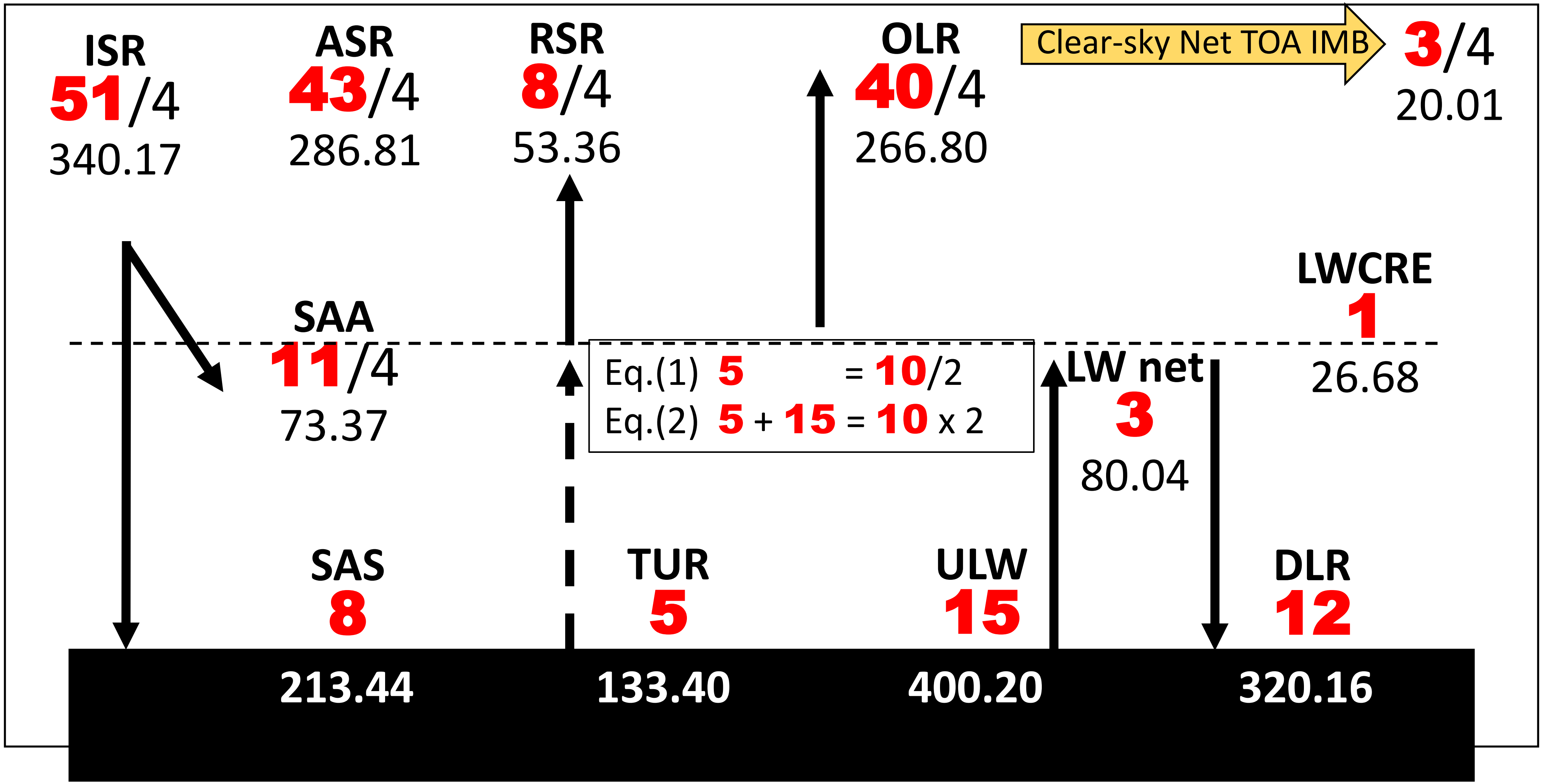
The only input parameter is TSI

Divide by 4



My clear-sky on the sphere.

The only input parameter is TSI



ISR
51/4
340.17

ASR
43/4
286.81

RSR
8/4
53.36

OLR
40/4
266.80

Clear-sky Net TOA IMB
3/4
20.01

LWCRE
1
26.68

SAA
11/4
73.37

Eq.(1) 5 = 10/2
Eq.(2) 5 + 15 = 10 x 2

LW net
3
80.04

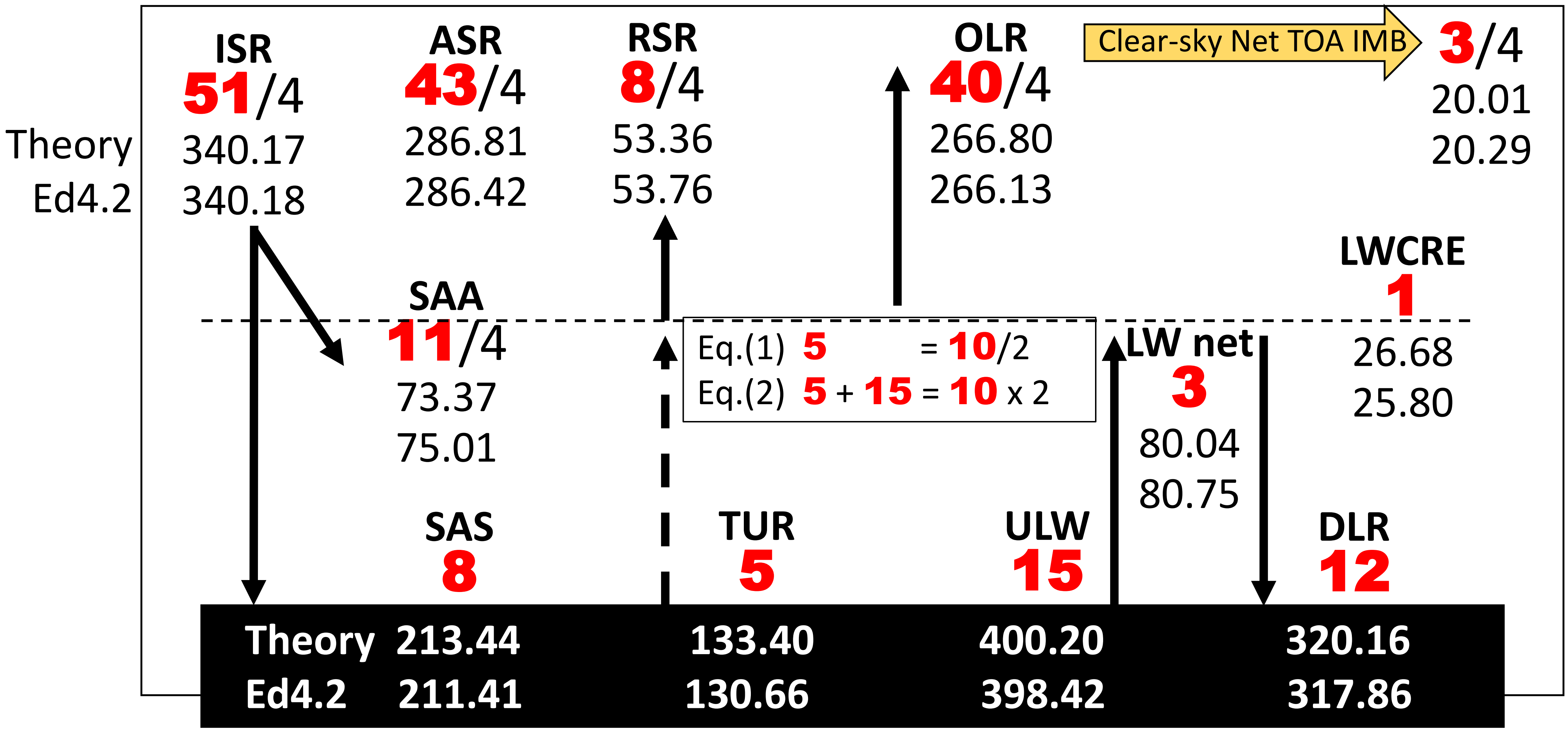
SAS
8
213.44

TUR
5
133.40

ULW
15
400.20

DLR
12
320.16

Theory vs EBAF Ed4.2, clear-sky



Theory
Ed4.2

ISR
51/4
340.17
340.18

ASR
43/4
286.81
286.42

RSR
8/4
53.36
53.76

OLR
40/4
266.80
266.13

Clear-sky Net TOA IMB
3/4
20.01
20.29

LWCRE
1
26.68
25.80

SAA
11/4
73.37
75.01

Eq.(1) **5** = **10**/2
Eq.(2) **5** + **15** = **10** x 2

LW net
3
80.04
80.75

SAS
8

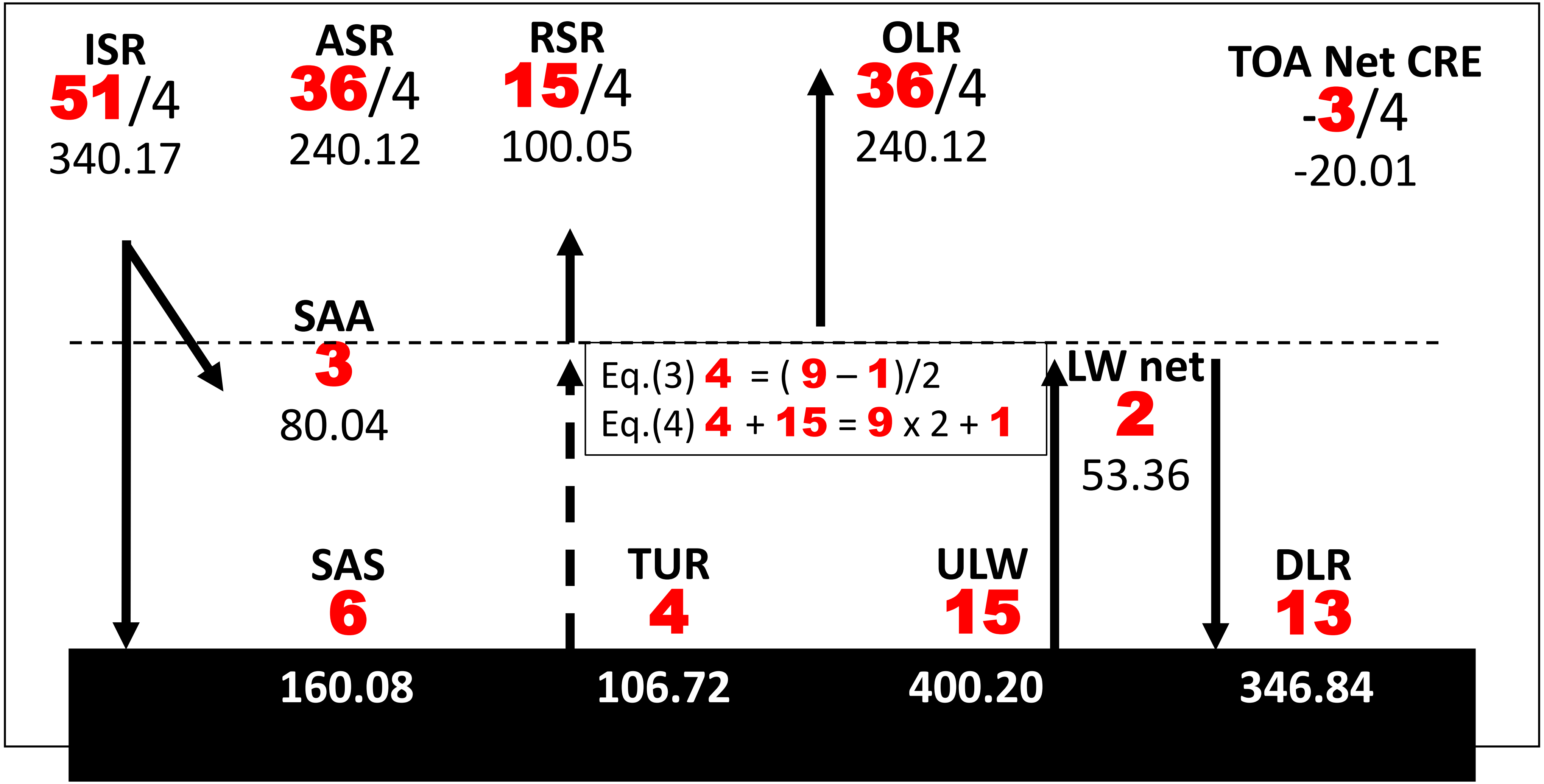
TUR
5

ULW
15

DLR
12

	SAS	TUR	ULW	DLR
Theory	**213.44**	**133.40**	**400.20**	**320.16**
Ed4.2	**211.41**	**130.66**	**398.42**	**317.86**

OLR **10** → **9**, My all-sky system on the sphere



ISR
51/4
340.17

ASR
36/4
240.12

RSR
15/4
100.05

OLR
36/4
240.12

TOA Net CRE
-**3**/4
-20.01

SAA
3
80.04

Eq.(3) **4** = (**9** – **1**)/2
Eq.(4) **4** + **15** = **9** x 2 + **1**

LW net
2
53.36

SAS
6
160.08

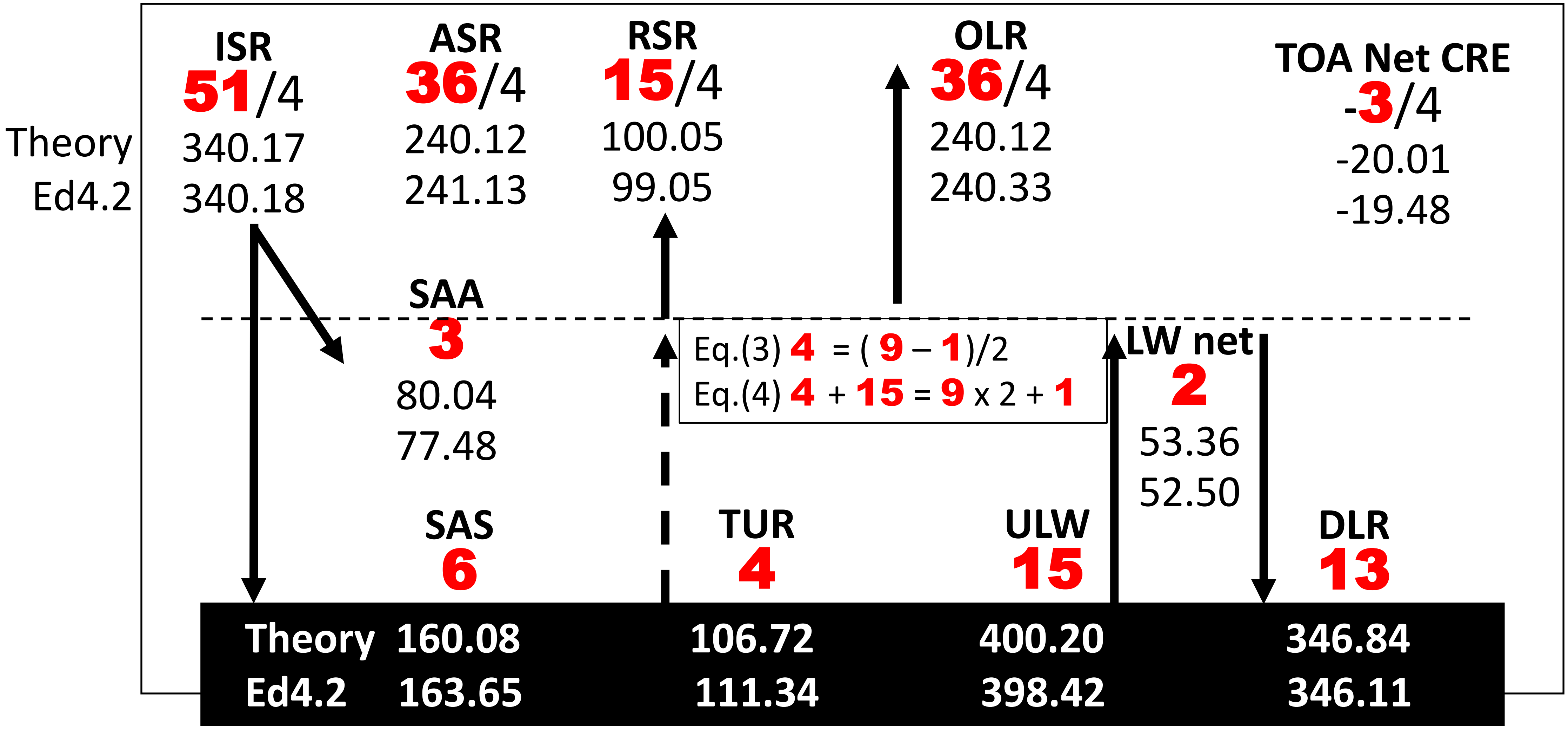
TUR
4
106.72

ULW
15
400.20

DLR
13
346.84

The only input parameter is TSI

Theory vs Ed4.2, all-sky, α = **15**/**51** = 5/17, β = **12**/**51** = 4/17



	ISR	ASR	RSR	OLR	TOA Net CRE
	51/4	**36**/4	**15**/4	**36**/4	-**3**/4
Theory	340.17	240.12	100.05	240.12	-20.01
Ed4.2	340.18	241.13	99.05	240.33	-19.48

	SAA	LW net
	3	**2**
Theory	80.04	53.36
Ed4.2	77.48	52.50

Eq.(3) **4** = (**9** – **1**)/2

Eq.(4) **4** + **15** = **9** x 2 + **1**

	SAS	TUR	ULW	DLR
	6	**4**	**15**	**13**
Theory	160.08	106.72	400.20	346.84
Ed4.2	163.65	111.34	398.42	346.11

Diff in ASR = 1.01 Wm^{-2}, in OLR = 0.21 Wm^{-2}, EEI = 0.80 Wm^{-2}

Table 2-1. Theory vs observation for global mean clear-sky fluxes for April 2000-March 2022 (W m^{-2})

	Clear-sky	**N**	**N × Unit**	**EBAF Ed4.2**	**Difference**
Clear-Sky TOA	SW insolation	**51**/4	340.17	340.18	0.01
	LW	**40**/4	266.80	266.13	-0.67
	SW	**8**/4	53.36	53.76	0.40
	Net	**3**/4	20.01	20.29	0.28
Clear-sky Surface	LW down	**12**	320.16	317.86	-2.30
	LW up	**15**	400.20	398.61	-1.59
	LW Net	**-3**	-80.04	-80.75	-0.71
	SW Net	**8**	213.44	211.41	-2.03
	SW + LW Net	**5**	133.40	130.66	-2.74

Table 4-1. Theory vs observation for global mean TOA and surface fluxes and CREs for EBAF Edition 4.2 for April 2000 to March 2022 (W m^{-2}).

	All-sky	**N**	**N** × **Unit**	**EBAF Ed4.2**	**Diff**
TOA	SW insolation	**51**/4	340.17	340.18	0.01
	SW up	**15**/4	100.05	99.05	-1.00
	LW up	**36**/4	240.12	240.33	0.21
	TOT Net	0	0	0.8	0.80
Surface	SW Net	**6**	160.08	163.65	3.57
	LW down	**13**	346.84	346.11	-0.73
	LW up	**15**	400.20	398.42	-1.78
	LW Net	-**2**	-53.36	-52.31	1.05
	TOT Net	**4**	106.72	111.34	4.62
	CRE				
TOA	SW	-**7**/4	-46.69	-45.28	1.41
	LW	**1**	26.68	25.80	-0.88
	Net	-**3**/4	-20.01	-19.48	0.53

Concluding

- My talk: TOA SW Up is part of the **N**-system
- EEI: Not only ASR – OLR, but ΔASR(**N**) – ΔOLR(**N**)
- The meeting: EBAF Ed4.2 is closer to **N** in most components
- Earth Energy Budget: Eqs. (1) — (4) are compulsory

Last minute: extras, comments

EBAF-TOA Edition 4.2
23 years (March 2000 – February 2023)

- Observed :
- ISR = 340.19 Wm^{-2}
- TSI = 4.0034 × 340.19 = 1361.92 Wm^{-2}

- Theory with geodetic weighting:
- LWCRE = TSI/51 × (4/4.0034) = **1** = 26.68 Wm^{-2}
- LWCRE (with spherical weighting = 26.70 Wm^{-2}

It is frequently stated that
Net CRE = SW CRE + LW CRE

Yes, but by def.:

- TOA Net CRE ≡ RSR(clear) – RSR(all) + OLR(clear – OLR(all) =
- TOA Net CRE = ISR – ASR(clear) – [ISR – ASR(all)] + LWCRE =
- TOA Net CRE = ASR(all) – ASR(clear) + [OLR(clear) – OLR(all)] =
- TOA Net CRE = – [ASR(clear) – OLR(clear)] + EEI(all) = EEI(all) – EEI(clear).

In equilibrium (EEI (all) = 0):

- TOA net CRE = – EEI(clear) = – **3**/4 = – 20.01 Wm^{-2}
- TOA clear IMB = EEI(clear) = ASR – OLR = **43**/4 – **40**/4 = **3**/4 = 20.01 Wm^{-2}

To understand the global character of TOA Net CRE, no clouds are needed.

It depends only on clear-sky values: SW absorption and LW emission (and EEI(all)).

Clear-Sky Greenhouse Effect at GFDL

LWCRE (theory) = **1** = 26.68 ± 0.01 Wm^{-2}

G (clear, theory) = **15** – **10** = **5** = 133.40 ± 0.05 Wm^{-2}

G (GFDL AM4) = 133.4 ± 0.6 Wm^{-2}

Quantifying the Drivers of the Clear Sky Greenhouse Effect, 2000–2016

Shiv Priyam Raghuraman ✉, David Paynter, V. Ramaswamy (JGR 2019)

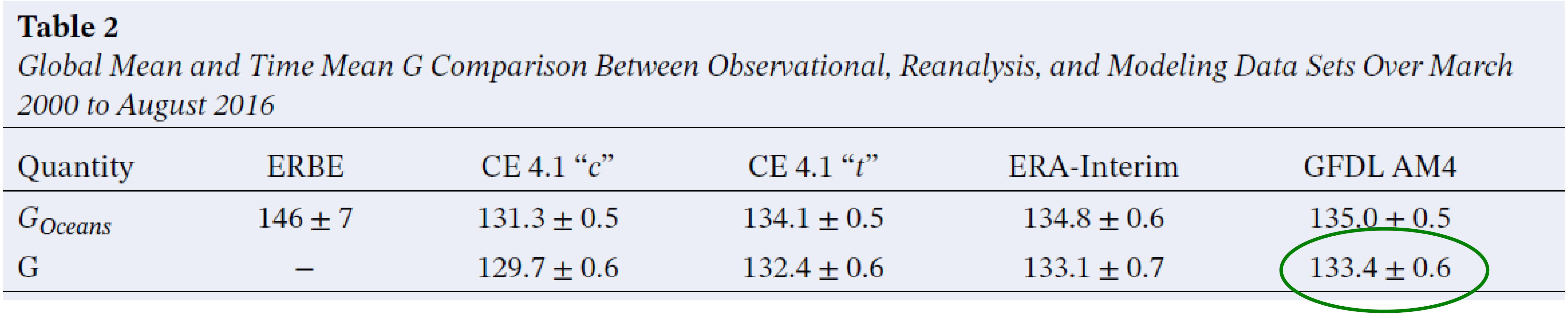


Table 2

Global Mean and Time Mean G Comparison Between Observational, Reanalysis, and Modeling Data Sets Over March 2000 to August 2016

Quantity	ERBE	CE 4.1 "c"	CE 4.1 "t"	ERA-Interim	GFDL AM4
G_{Oceans}	146 ± 7	131.3 ± 0.5	134.1 ± 0.5	134.8 ± 0.6	135.0 ± 0.5
G	–	129.7 ± 0.6	132.4 ± 0.6	133.1 ± 0.7	133.4 ± 0.6

Overall conclusion

This is not a ’just-so’ world.

Not “If this goes up, than that goes down” world.

This is a principled world.