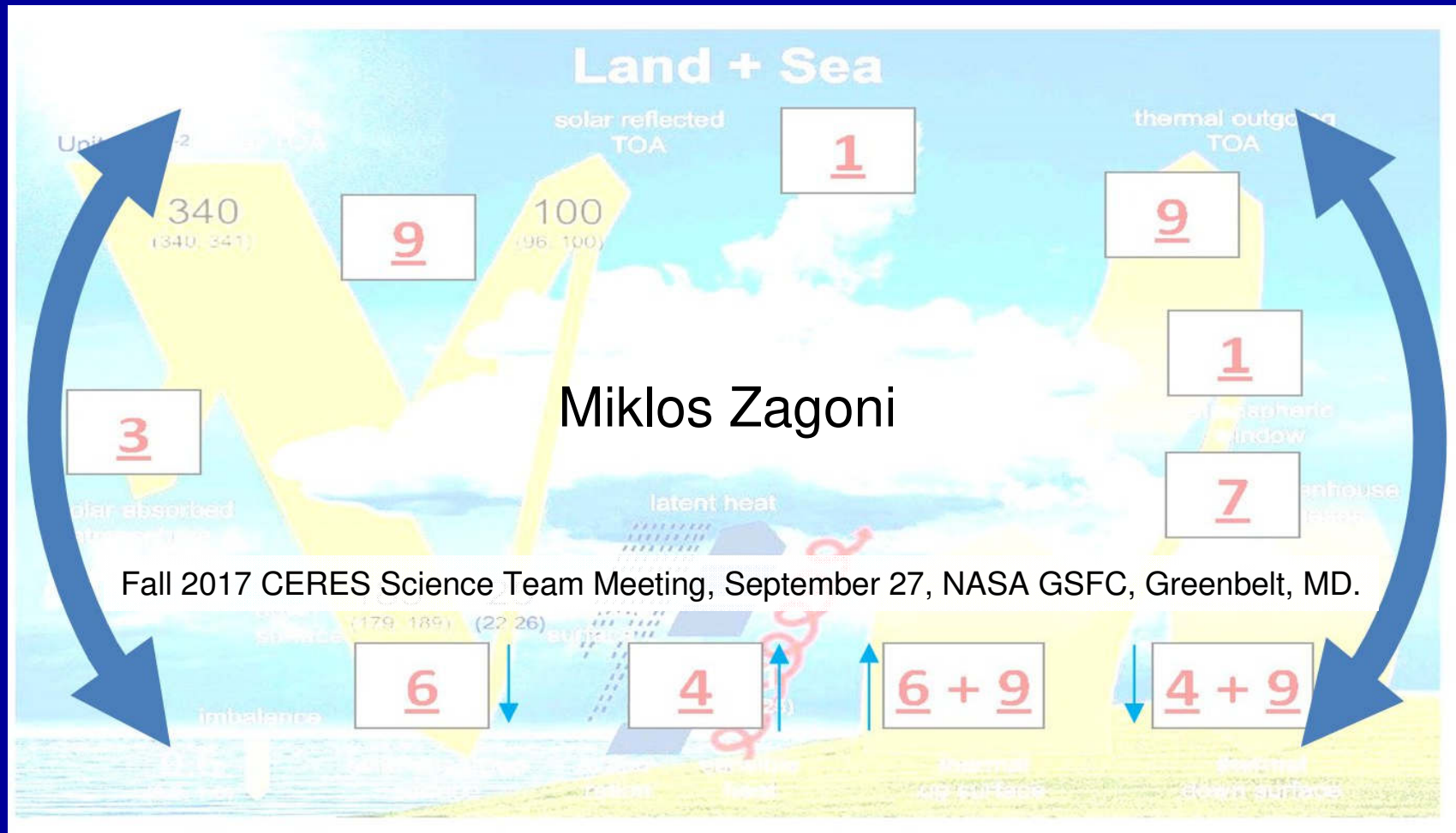# Patterns in the CERES Global Mean Data

Miklos Zagoni

Fall 2017 CERES Science Team Meeting, September 27, NASA GSFC, Greenbelt, MD.

"To search for something – though it be mushrooms –
or some pattern – is impossible, unless you look and try."
Dmitri Mendeleev

CERES_EBAF-Surface_Ed4.0
Data Quality Summary (May 26, 2017)

Table 5-1. Global mean surface fluxes in W m^{-2} computed from EBAF Ed4.0 and EBAF Ed2.8 for March 2000-February 2016.

All-sky	Ed4	Ed2.8	Ed4 – Ed2.8
TOA SW insolation	340.0	339.9	0.17
SW down	187.0	186.5	0.57
SW up	23.4	24.1	-0.76
SW net[1]	163.7	162.3	1.33
LW down	345.0	345.2	-0.18
LW up	398.3	398.3	0.07
LW net[1]	-53.4	-53.1	-0.25
SW+LW net	110.3	109.2	1.08
Clear-sky			
TOA SW insolation	340.0	339.9	0.17
SW down	243.7	244.1	-0.33
SW up	29.8	29.7	0.07
SW net[1]	213.9	214.3	0.41
LW down	314.1	316.3	-2.20
LW up	397.6	398.4	-0.81
LW net[1]	-83.5	-82.1	1.39
SW+LW net[1]	130.4	132.2	-1.80

[1] Net is computed by downward – upward.

Fred Rose et al ## Global Means(Mar2000-Feb2016)

All Sky	Ed4	Ed2.8	Ed4 –Ed2.8
TOA SW Insolation	340.04	339.87	0.17
TOA SW Up	*99.23*	*99.62*	*-0.39*
TOA LW Up	*240.14*	*239.60*	*0.54*
SFC SW Down	187.04	186.47	0.57
SFC SW Up	23.37	24.13	-0.76 (3.1%)
SFC LW Down	344.97	345.15	-0.18
SFC LW Up	398.34	398.27	0.07

Clear Sky	Ed4	Ed2.8	Ed4 –Ed2.8
TOA SW Insolation	340.04	339.87	0.17
TOA SW Up	*53.41*	*52.50*	*0.91 (1.73%)*
TOA LW Up	*268.13*	*265.59*	*2.54*
SFC SW Down	243.72	244.06	-0.33
SFC SW Up	29.81	29.74	0.07
SFC LW Down	314.07	316.27	-2.20
SFC LW Up	397.59	398.40	-0.81

Pattern 1. SFC energy in = 2 × TOA LW out

Clear-sky	Ed2.8
TOA SW in	339.87
TOA SW up	52.50
TOA LW up	265.59
SFC SW down	244.06
SFC SW up	29.74
SFC SW in (down − up)	214.32
SFC LW down	316.27
SFC SW + LW absorbed	530.59
SFC LW up	398.40
SFC SW + LW net	132.19
G = SFC LW up − TOA LW up	132.81
2TOA LW up	531.18
Diff	−0.59

**Clear-sky, Ed2.8
Surface energy absorbed**
SW + LW (Wm^{-2}):

(SW down − SW up) + LW down
= (244.06 − 29.74) + 316.27
= 214.32 + 316.27
= 530.59

TOA LW out = 265.59
2 × TOA LW out =
= 531.18

Diff = −0.59 Wm^{-2}

$$214.32 + 316.27 = 2 \times 265.59 - 0.59$$

Clear-sky, Ed2.8, time period 2001-2015, climate year:

	SW down	SW up	SW abs	LW abs	E(SFC)	OLR	2OLR	Diff
CLIM 1	255.35	31.34	224.01	306.27	530.28	262.43	524.86	5.42
CLIM 2	251.86	29.86	222	307.98	529.98	262.78	525.56	4.42
CLIM 3	246.89	30.09	216.8	311.09	527.89	263.42	526.84	1.05
CLIM 4	242.26	31.63	210.63	315.14	525.77	265.01	530.02	-4.25
CLIM 5	237.33	32.21	205.12	320.27	525.39	267.18	534.36	-8.97
CLIM 6	233.41	28.67	204.74	325.70	530.44	269.05	538.1	-7.66
CLIM 7	231.63	25.72	205.91	328.35	534.26	269.75	539.5	-5.24
CLIM 8	233.65	24.42	209.23	327.05	536.28	269.12	538.24	-1.96
CLIM 9	239.24	25.80	213.44	321.82	535.26	267.58	535.16	0.1
CLIM 10	247.06	29.92	217.14	315.28	532.42	265.25	530.5	1.92
CLIM 11	253.97	33.73	220.24	309.57	529.81	263.26	526.52	3.29
CLIM 12	256.35	33.52	222.83	306.74	529.57	262.38	524.76	4.81
Average	244.08	29.74	214.34	316.27	530.61	265.60	531.20	-0.59

$$214.34 + 316.27 = 530.61 = 2 \times 265.60 - 0.59$$

E(SFC in, clear-sky) = (SW down – SW up) + LW in = 2OLR – EEI

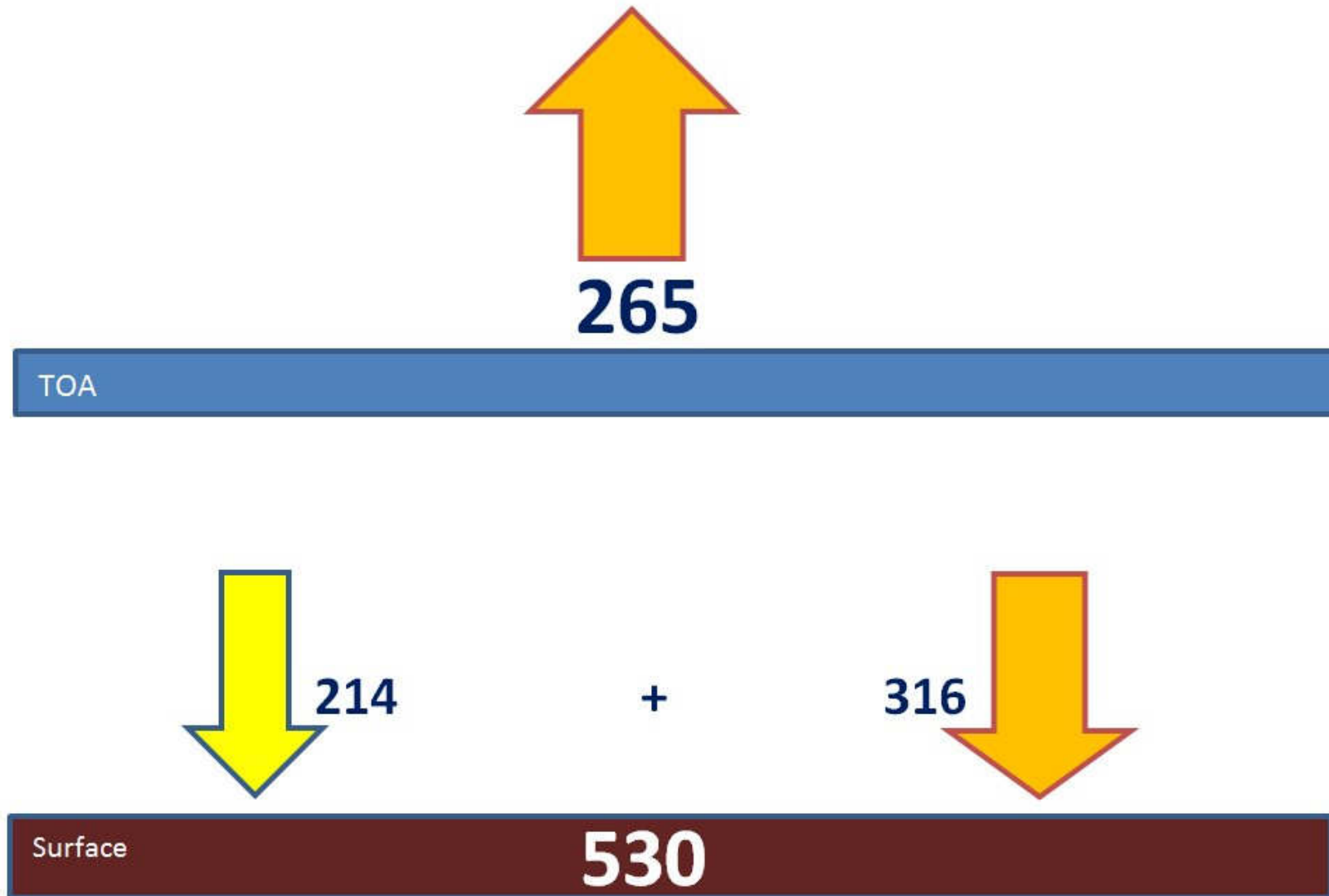# CERES 26th STM October 2016, Martin Wild, slide #36
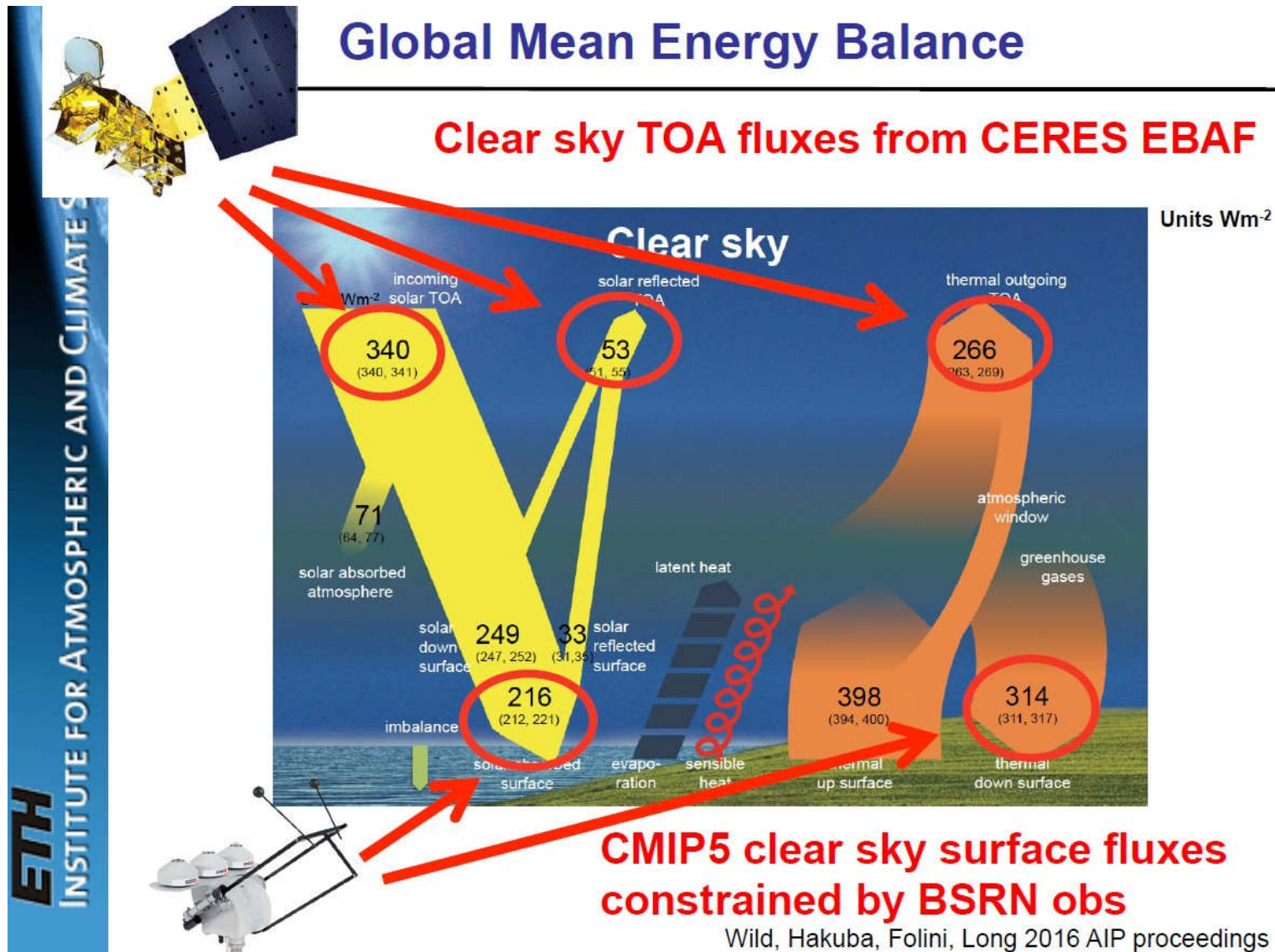
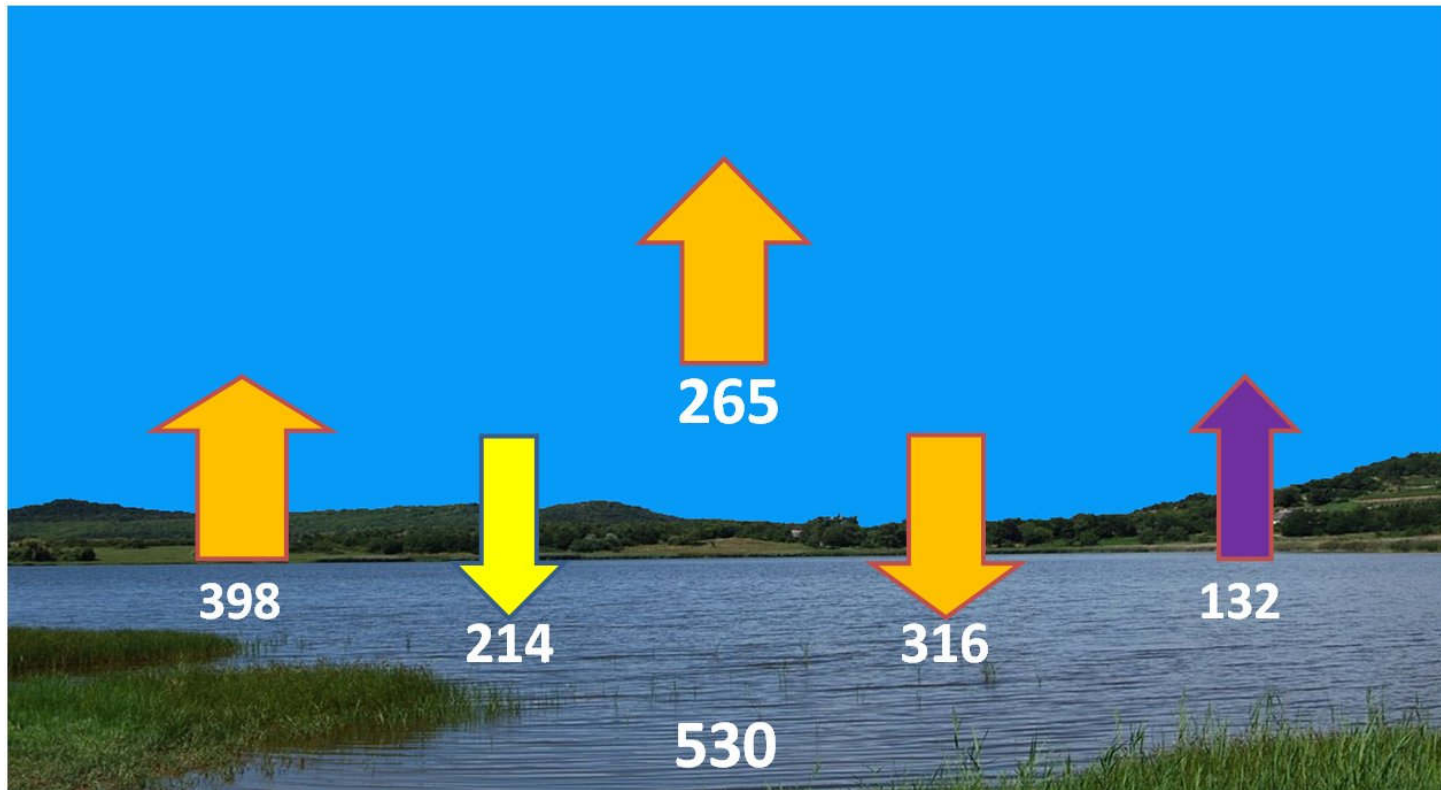TOA and SFC fluxes from independent data sources

CERES 26th STM October 2016, Martin Wild, slide #36
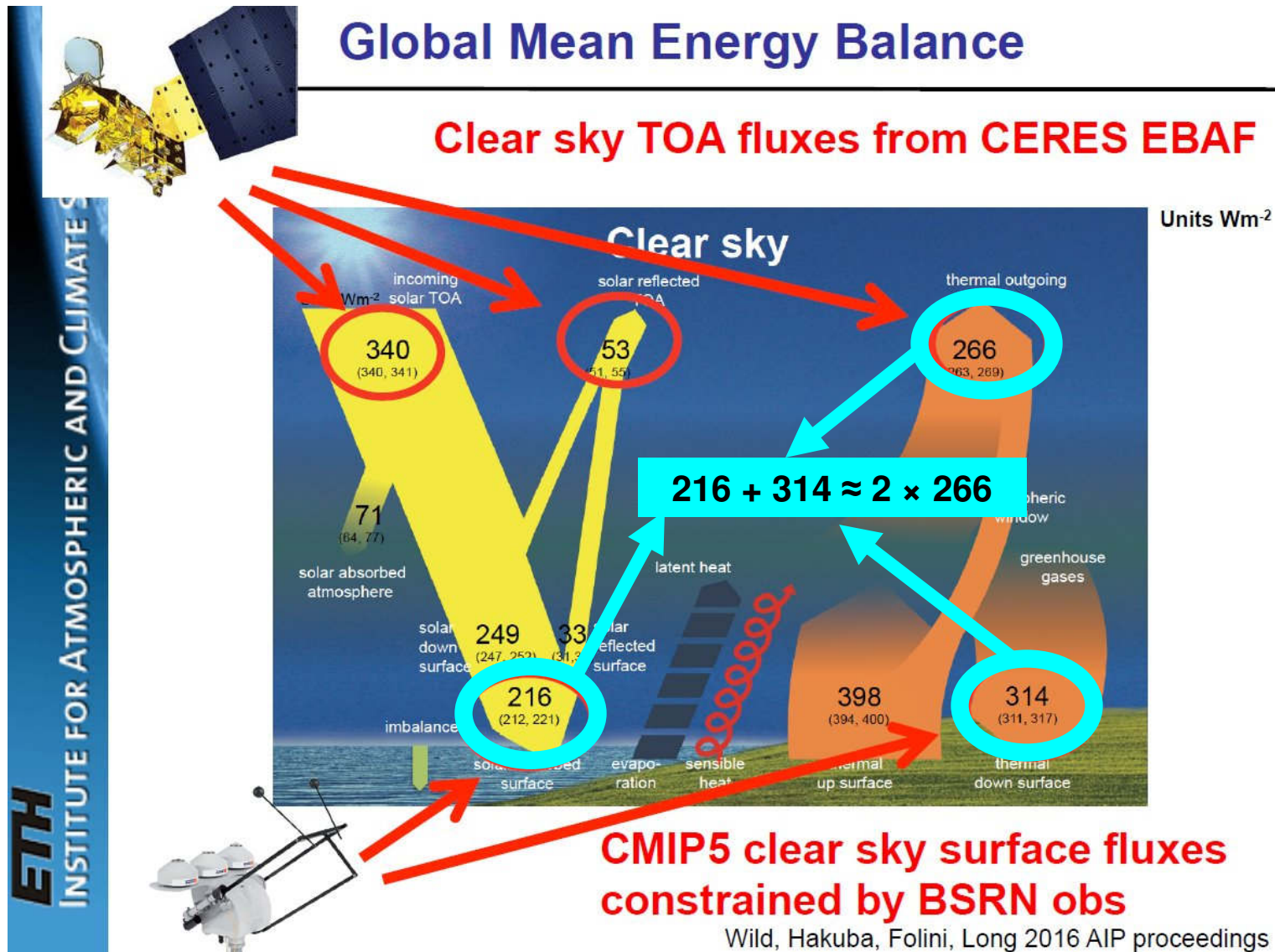
solar absorbed surface + thermal down surface = 2 × thermal outgoing TOA

Energy (surface in, clear sky) = SW↓ abs + LW↓ abs = 2 × OLR

Surface energy budget, clear-sky, CERES EBAF Ed2.8

Solar absorbed + thermal absorbed = 2 outgoing longwave TOA

$$214.34 + 316.28 = 2 \times 265.6 - 0.58 \ \mathrm{Wm^{-2}}$$

$$\text{SW abs}\downarrow + \text{LW abs}\downarrow = 2\text{OLR(clear)} - 0.58 \ \mathrm{Wm^{-2}}$$

=> Net planetary imbalance for July 2005-June 2010: 0.58±0.43 Wm⁻²

Pattern 2. SFC Net = G

Clear-sky	Ed2.8
TOA SW in	339.87
TOA SW up	52.50
TOA LW up	265.59
SFC SW down	244.06
SFC SW up	29.74
SFC SW in	214.32
SFC LW in	316.27
SFC SW + LW absorbed	530.59
SFC LW up	398.40
SFC Net	**132.19**
G	**132.81**
Diff	−0.62

SFC Net Flux (non-radiative)
= SFC (SW in + LW in)
− SFC LW up

SFC Net = 214.32 + 316.27
− 398.40
= **132.19**

G = SFC LW up − TOA LW up
= ULW − OLR =
= **132.81**

Diff (W m^{-2})
= −0.62
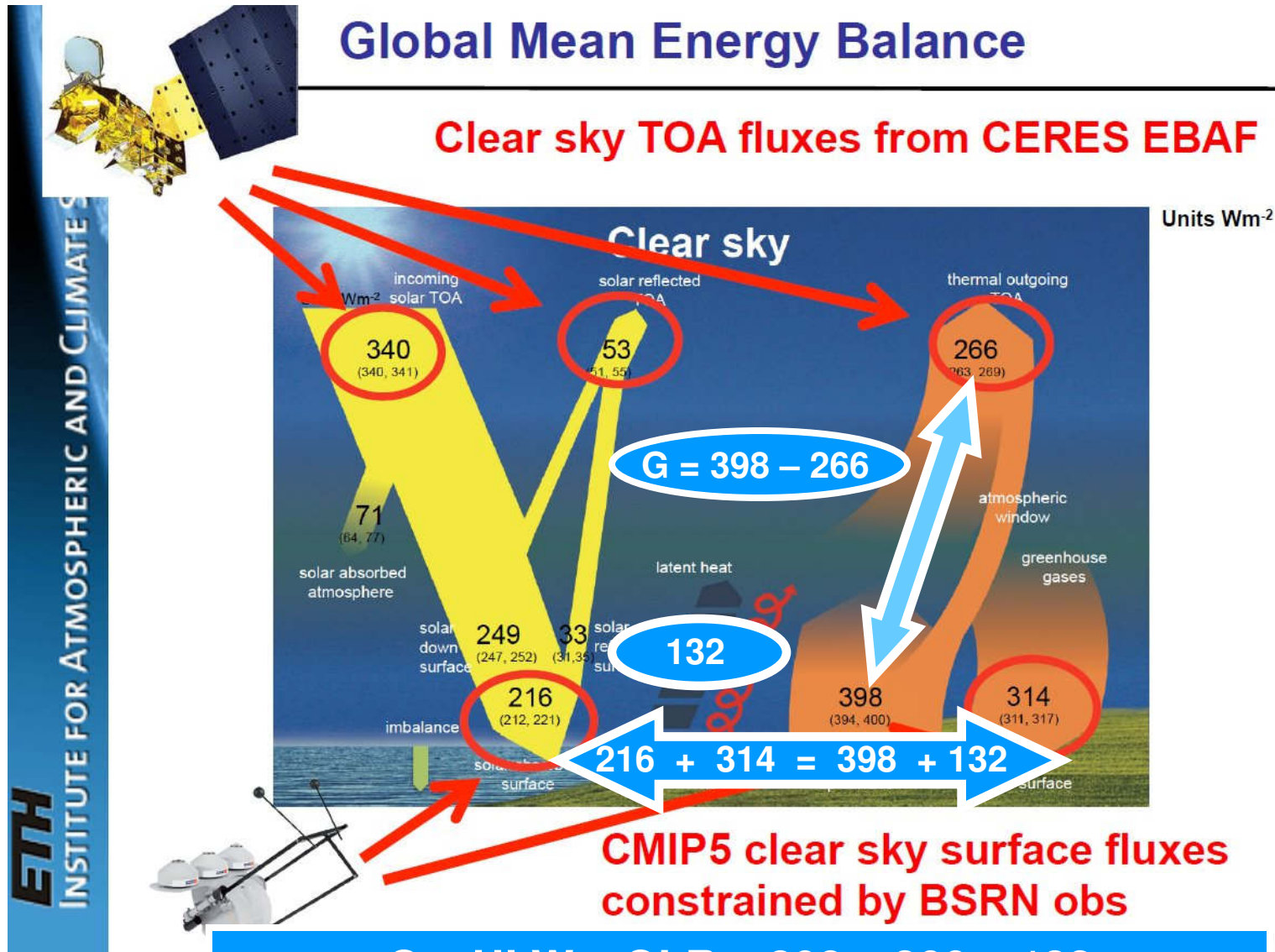
CERES 26th STM October 2016, Martin Wild, slide #36
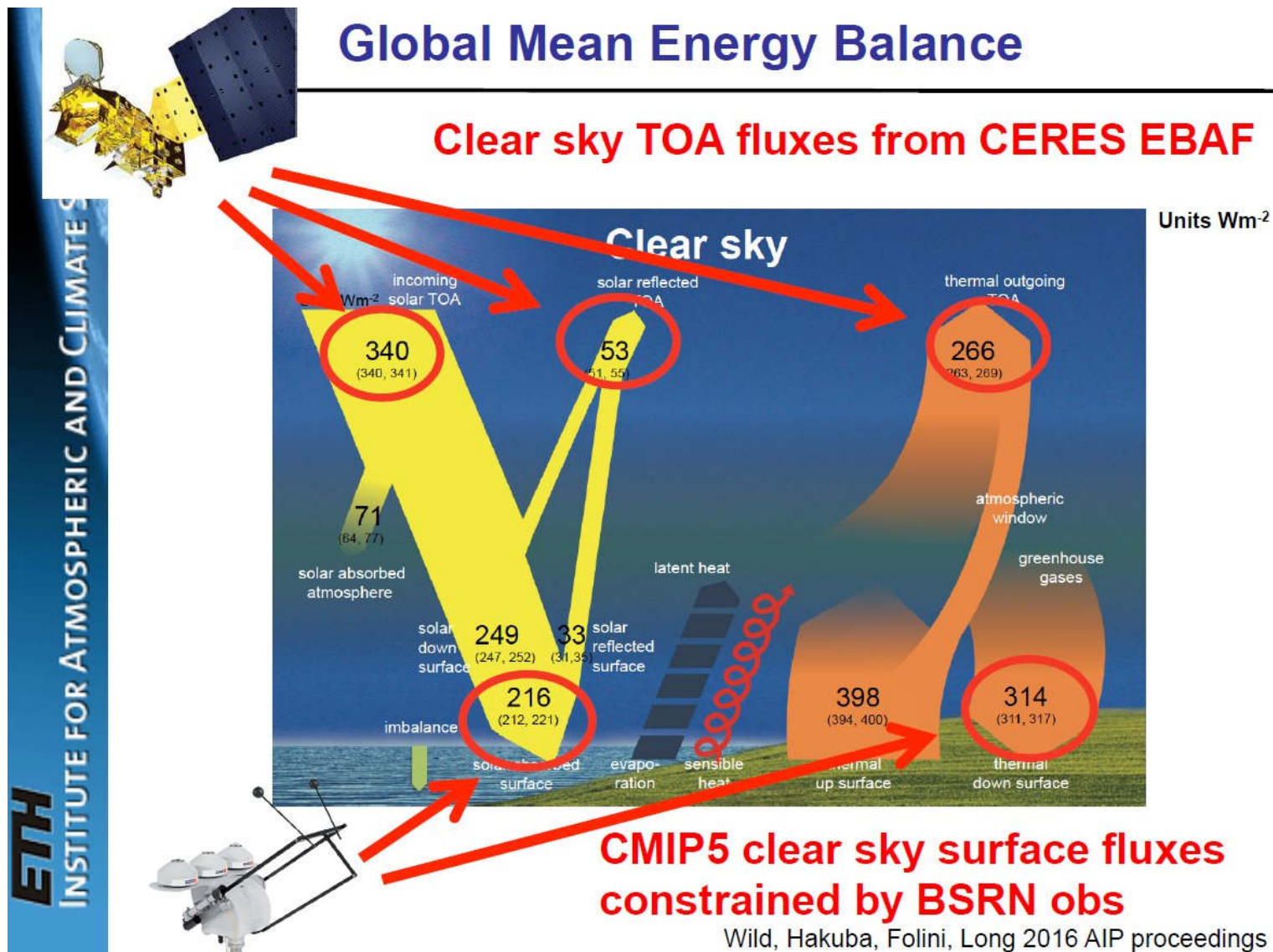
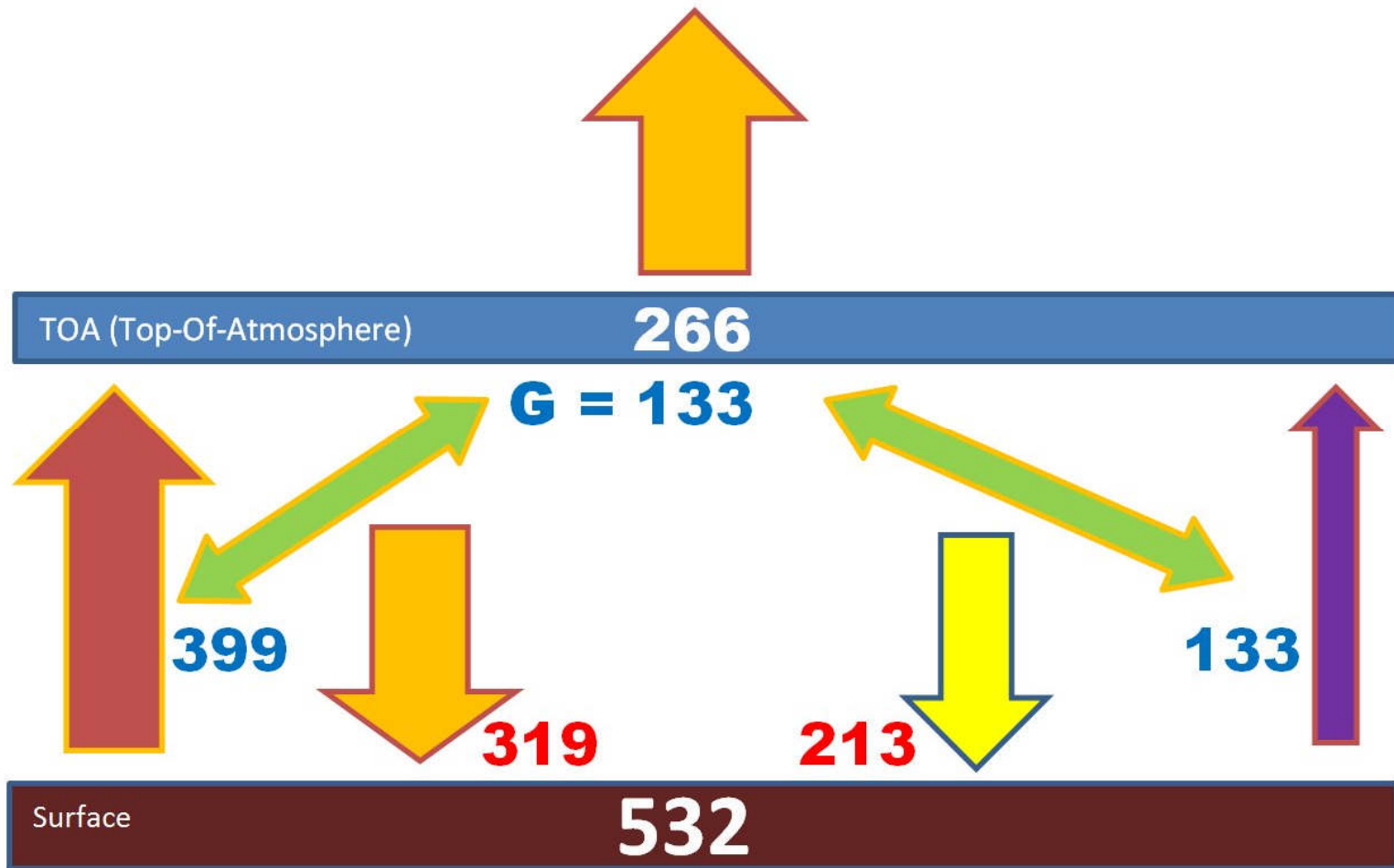TOA and SFC fluxes from independent data sources

G = SFC Net (turb, non-rad)

Global Mean Energy Balance

Clear sky TOA fluxes from CERES EBAF

Units Wm⁻²

Clear sky

incoming solar TOA — 340 (340, 341)

solar reflected TOA — 53 (51, 55)

thermal outgoing TOA — 266 (263, 269)

71 (64, 77)

solar absorbed atmosphere

latent heat

atmospheric window

greenhouse gases

G = 398 – 266

solar down surface — 249 (247, 252)

33 (31, 35) solar reflected surface

132

398 (394, 400)

314 (311, 317)

imbalance

216 (212, 221)

216 + 314 = 398 + 132

CMIP5 clear sky surface fluxes constrained by BSRN obs

G = ULW – OLR = 398 – 266 = 132
SFC Net (SH + LH) = 216 + 314 – 398 = 132

Clear-sky ratios

G / OLR / ULW / E(SFC) = 133 / 266 / 399 / 532 = **1 / 2 / 3 / 4**

Clear-sky, Ed2.8, climate year, 2001-2015

	ULW	OLR	G	Net SFC	ULW+G	2OLR	Diff
CLIM 1	388.3	262.43	125.87	141.98	514.17	524.86	10.69
CLIM 2	389.89	262.78	127.11	140.09	517	525.56	8.56
CLIM 3	393.31	263.42	129.89	134.57	523.2	526.84	3.64
CLIM 4	398.51	265.01	133.5	127.26	532.01	530.02	-1.99
CLIM 5	403.29	267.18	136.11	122.09	539.4	534.36	-5.04
CLIM 6	407.64	269.05	138.59	122.8	546.23	538.1	-8.13
CLIM 7	409.1	269.75	139.35	125.17	548.45	539.5	-8.95
CLIM 8	407.83	269.12	138.71	128.46	546.54	538.24	-8.30
CLIM 9	403.85	267.58	136.27	131.41	540.12	535.16	-4.96
CLIM 10	397.76	265.25	132.51	134.65	530.27	530.5	0.23
CLIM 11	392.27	263.26	129.01	137.54	521.28	526.52	5.24
CLIM 12	389.00	262.38	126.62	140.57	515.62	524.76	9.14
average	**398.39**	**265.60**	**132.80**	**132.22**	**531.19**	**531.20**	**0.01**

ULW **–** G = OLR (def.); **Data**: G = Net SFC (= SH+LH)
ULW + G = 2OLR, Diff = **0.01** (!!!) W/m² =>
G = OLR/2 <=> g = G/ULW = 1/3

Greenhouse effect and normalized greenhouse factors, years 2001 – 2015, g = G/ULW.

Integer ratios: **g(all)** = 6/15 = 2/5 = **0.4**; **g(clear)** = 5/15 = **1/3**

g(all-sky) and g(clear-sky), CERES EBAF Edition 2.8 (March 27, 2015), monthly mean

Theoretical lattice state at g(all-sky) = 6/15 = 2/5 = **0.4** and g(clear-sky) = 5/15 = 1/3 = **0.3333**

Best fit: g(all-sky) = **0.40006** (in year 2015), g(clear-sky) = **0.33338** (in year 2011)

Increase: g(all-sky) from 0.397 to 4.000; g(clear-sky) from 0.3313 to 0.3355

2001		G = ULW - OLR	g = G/ULW		
ULW	OLR(all-sky)	G(all-sky)	g(all-sky)	OLR(clear-sky)	g(clear-sky)
386.52	236.38	150.14	0.378000	262.3	0.321381
387.61	236.47	151.14	0.375000	262.54	0.32267
391.6	236.94	154.66	0.381000	263.06	0.328243
397.01	237.91	159.1	0.390000	265.06	0.332359
402.96	240.44	162.52	0.399000	267.65	0.33579
405.53	241.76	163.77	0.406000	268.82	0.337114
407.84	243.54	164.3	0.413000	269.85	0.338343
407.41	244.1	163.31	0.416000	269.77	0.337841
403.6	241.67	161.93	0.417000	267.36	0.337562
398.07	239.21	158.86	0.399000	265.59	0.332806
392.62	237.55	155.07	0.395000	264.09	0.327365
388.71	236.21	152.5	0.392000	262.55	0.324561
Average	**239.35**	**158.11**	**0.396754**	**265.72**	**0.331336**

2010	OLR(all)	G	g(all)	OLR(clear)	g(clear)
388.1	237.59	150.51	0.387812	262.85	0.322726
389.76	237.47	152.29	0.390728	262.85	0.325611
393.82	238.31	155.51	0.394876	264.01	0.329618
399.41	238.16	161.25	0.40372	264.94	0.336672
404.04	240.59	163.45	0.404539	267.39	0.338209
407.37	242.28	165.09	0.405258	268.59	0.340673
408.44	243.36	165.08	0.404172	269.23	0.340833
407.45	243.86	163.59	0.401497	268.8	0.340287
403.91	242.07	161.84	0.400683	267.34	0.33812
398.44	239.44	159	0.399056	265.16	0.334505
392.67	237.56	155.11	0.395014	263.27	0.329539
387.61	236.18	151.43	0.390676	261.87	0.324398
			0.398169		**0.333433**

2011	OLR(all)	G	g(all)	OLR(clear)	g(clear)
386.56	235.86	150.7	0.389849	261.37	0.323857
388.4	237.52	150.88	0.388465	262.45	0.324279
392.56	237.85	154.71	0.394105	262.84	0.330446
398.11	238.17	159.94	0.401748	264.42	0.335812
403.06	239.29	163.77	0.406317	266.37	0.339131
407.06	241.97	165.09	0.405567	268.68	0.33995
408.41	243.95	164.46	0.402684	269.79	0.339414
407.51	244.05	163.46	0.401119	268.91	0.340114
403.66	242.92	160.74	0.398206	267.47	0.337388
398.28	239.02	159.26	0.399869	264.73	0.335317
391.79	236.81	154.98	0.395569	262.76	0.329335
388.35	235.99	152.36	0.392327	261.92	0.325557
			0.397985		**0.33338**

Pattern 3. Clear-sky integer ratios

Costa and Shine (2012) Line-By-Line

- ULW   = 386 Wm^{-2}
- OLR   = 259 Wm^{-2}
- ATM   = 194 Wm^{-2}
- G   = 127 Wm^{-2}
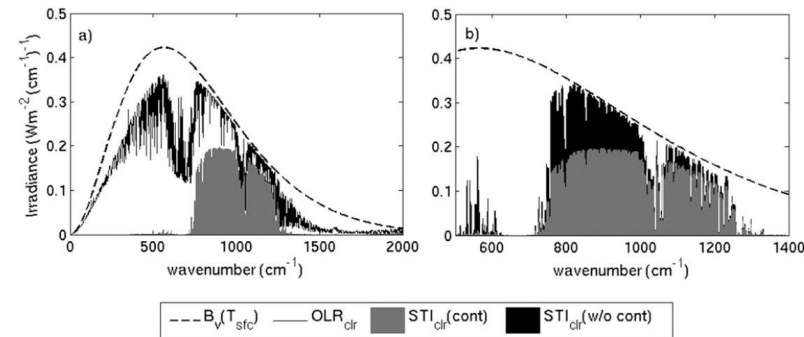- STI   = 65 Wm^{-2}

FIG. 1. Spectral distribution of the clear-sky Earth Radiation Budget components [W m^{-2} (cm^{-1})$^{-1}$] using a global-mean atmosphere. (a) Longwave irradiance emitted by surface $B_\nu(T_{sfc})$ assuming it to be a blackbody, the outgoing longwave radiation (OLR$_{clr}$), and surface transmitted irradiance including the water vapor continuum [STI$_{clr}$ (cont)]. (b) As in (a), over a smaller wavenumber interval, but includes, instead of OLR$_{clr}$, the surface transmitted irradiance when the water vapor continuum is excluded [STI$_{clr}$(w/o cont)].

	STI	G	ATM	OLR	ULW	2OLR
CS12 =	65	127	194	259	386	518
Pattern	65 /	130 /	195 /	260 /	390 /	520
Ratios	1 /	2 /	3 /	4 /	6 /	8
Diff	0	3	1	1	4	2 (Wm^{-2})

1.   **E(SFC, clear) = 2OLR(clear)**
2.   **G(clear) = SFC Net (clear)**
3.   **G(clear) = OLR(clear)/2**

These are **NOT** universal planetary rules.

- They cannot be deduced from the known *energy in = energy out* balance requirements
- They describe a unique, very specific state
- They are far from being valid, for example, on the Mars:
- The Martian ULW is 123 Wm^{-2},
  OLR = 110, G = 13 Wm^{-2}, therefore
  ULW + G $\ll$ 2OLR
  ULW – OLR $\ll$ 2OLR – ULW
  G $\ll$ OLR/2.

Read et al. (2015) QJRMS, our additions in textboxes
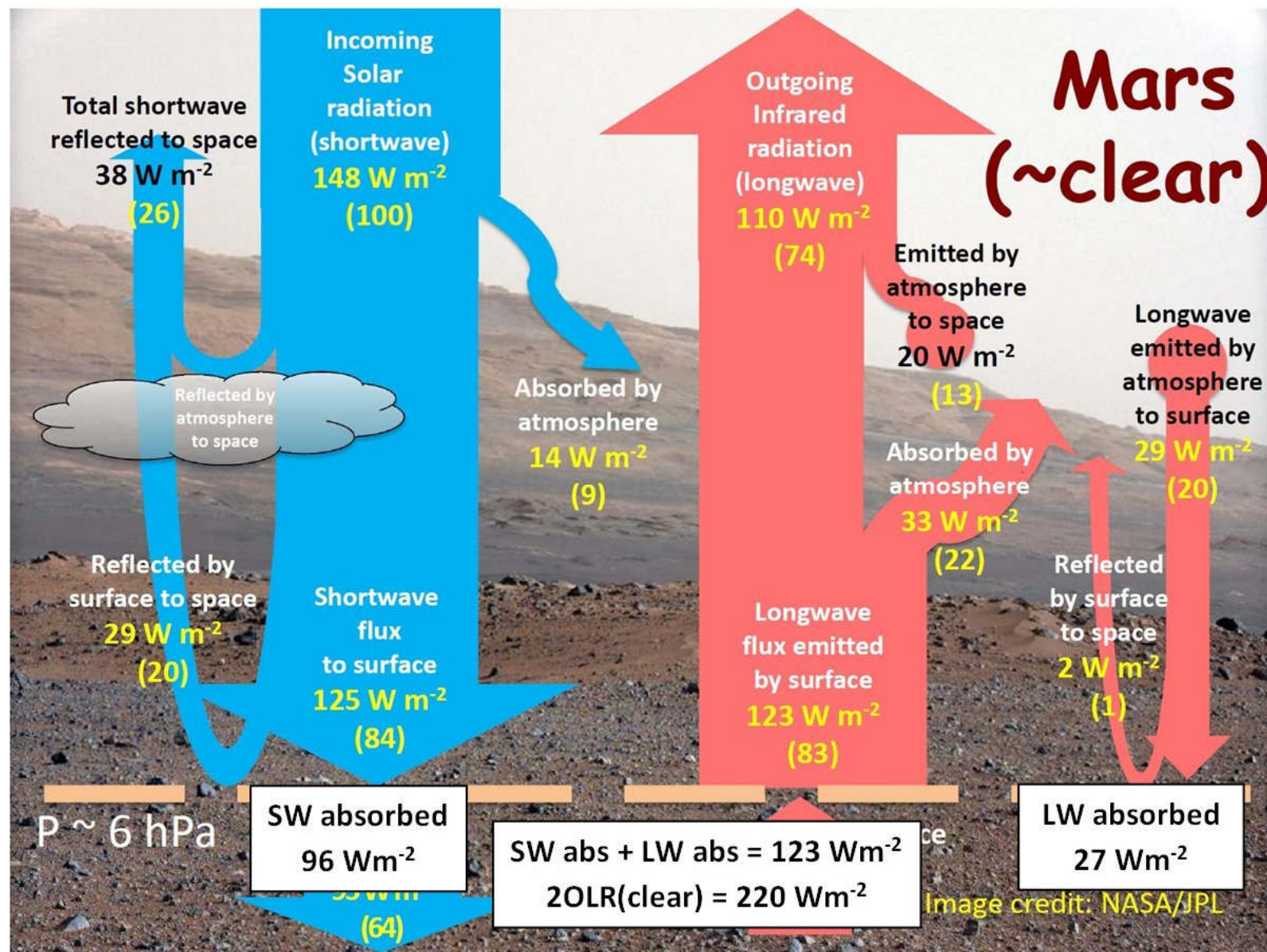
Energy (surface, Mars) = SW in + LW in << 2OLR; 2G = 26 W/m² << OLR

They belong to a specific geometry

- It is like the **IR-opaque limit**:
  a planet surrounded by a

    SW-transparent
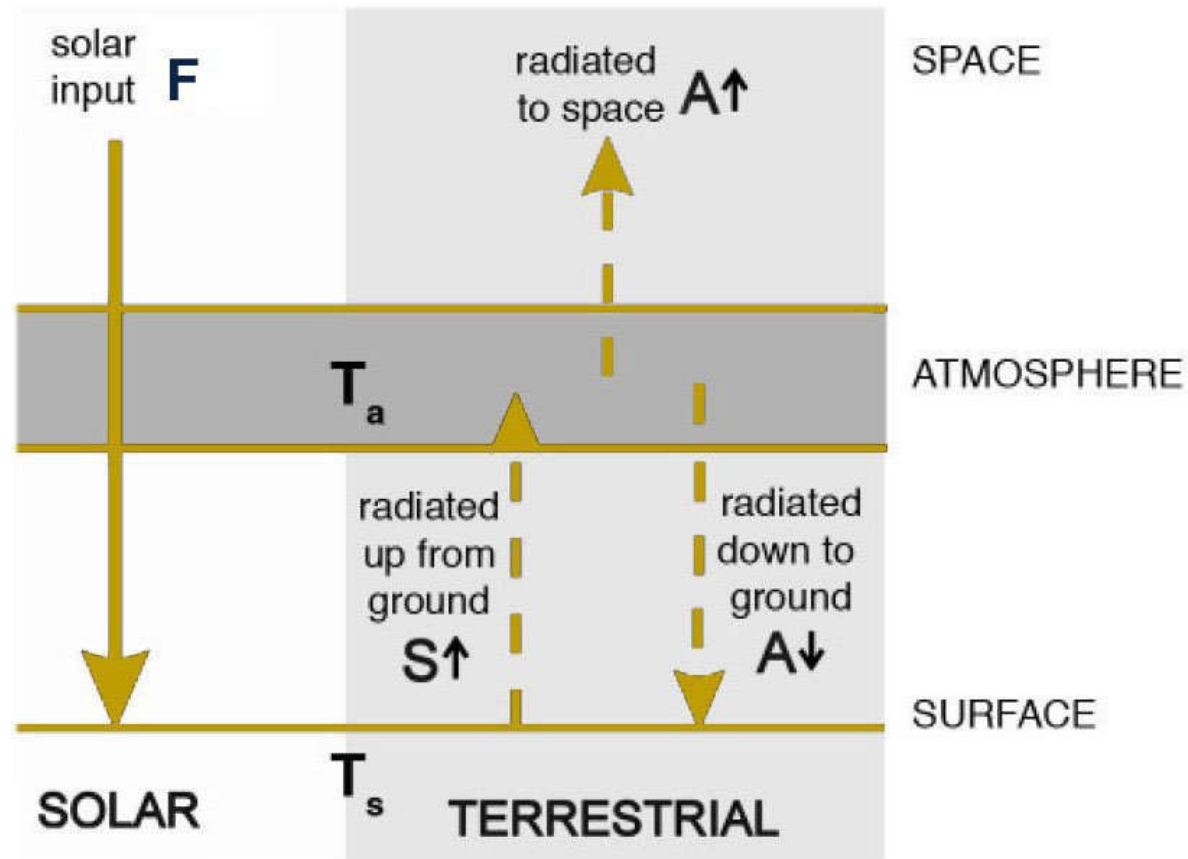   LW-opaque
    non-turbulent

  "**glass-shell**" atmosphere.

- The surface radiation here is exactly **twice**
  the outgoing longwave radiation because of
  the construction:

Model: an idealized glass-shell geometry
SFC (SW in + LW in) = SFC LW out = 2 TOA LW out
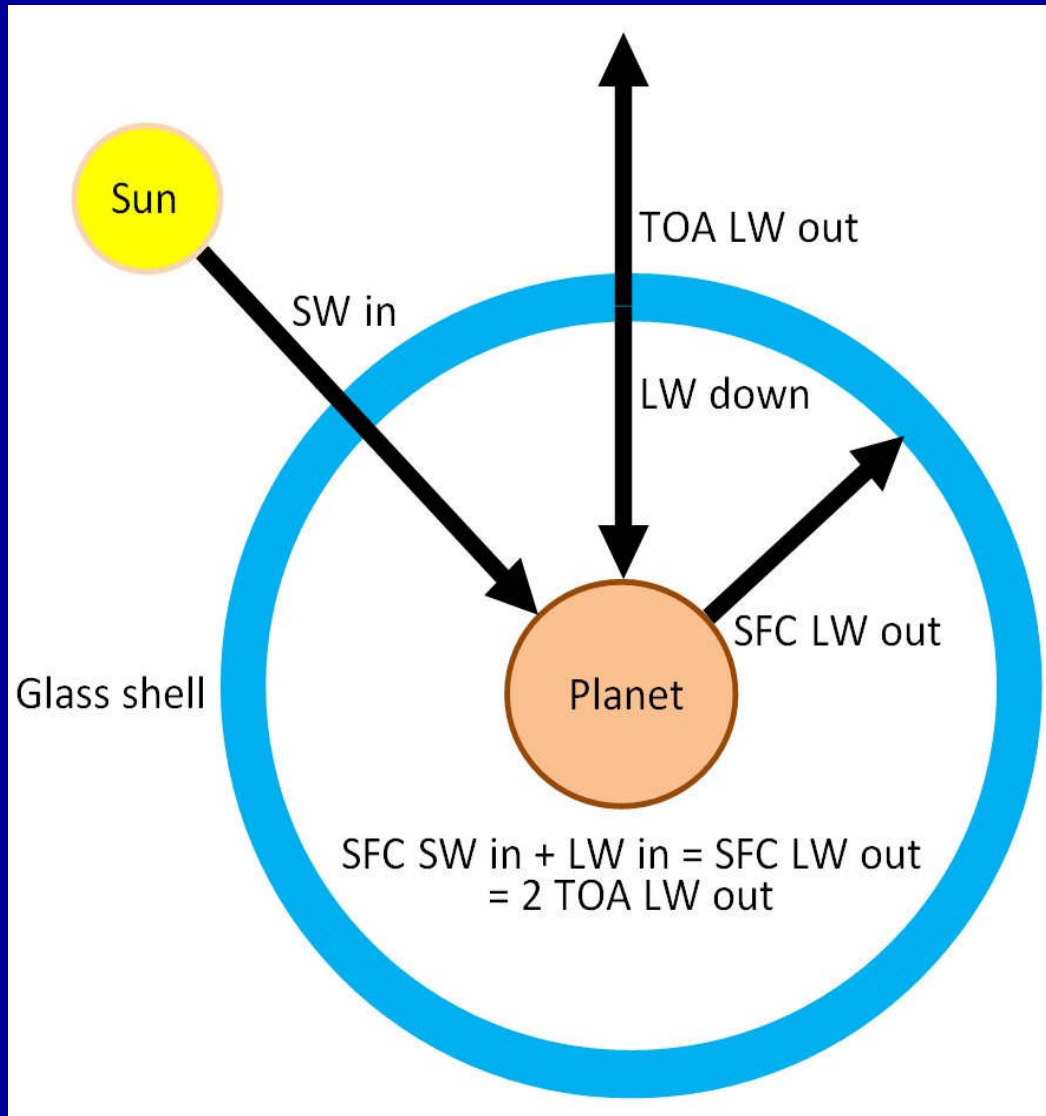
After Mashall and Plumb (2008, Fig. 2.7)
SW-transparent, LW-opaque, non-turbulent

$$F(SW) + A(LW) = S(LW) = 2A(LW)$$
$$G = S - A = A = F$$

All-sky

All-sky	Ed2.8
TOA SW in	339.87
TOA SW up	99.62
TOA LW up	239.60
SFC SW down	186.47
SFC SW up	24.13
SFC SW in	162.34
SFC LW down	345.15
SFC SW + LW absorbed	**507.49**
SFC LW up	398.27
SFC Net	109.22
G	158.67
SFC LWCRE	28.88
2TOA LW Up + SFC LWCRE	**508.08**
Diff	−0.59

Ed2.8

SFC energy in:
SW in = 162.35 W/m²
LW in = 345.15 W/m²
SFC (SW in + LW in)
= **507.5**

SFC energy out:
LW up + Net =
= **398 + 109** (+ EEI 0.5)

2OLR = 2 × 239.6
= **479.2** W/m²

Diff = 507.5 − 479.2
= **28.3** W/m²

28 W/m² difference…

- How much was the cloud longwave radiative effect (LWCRE)?

- LWCRE = 28 W/m².

- What we have here it is this:
  SFC energy in (SW + LW) =
  = 2OLR(all) + SFC LWCRE.

- *Now THAT might be meaningful* :

- **The surface energy budget in the all-sky has the same form as in the clear-sky case, PLUS one LW cloud radiative effect.**

Pattern 4. E(SFC) = 2OLR(all) + LWCRE

CLIMYEAR	SW abs	LW abs	E(SFC)	OLR(all)	LWCRE	2OLR+LWCRE	Diff
CLIM 1	166.24	335.34	501.58	236.77	29.51	503.05	-1.47
CLIM 2	167.41	337.07	504.48	237.35	29.58	504.28	0.2
CLIM 3	166.63	339.65	506.28	237.72	28.92	504.36	1.92
CLIM 4	162.87	344.47	507.34	238.42	29.61	506.45	0.89
CLIM 5	157.84	349.06	506.9	240.24	28.64	509.12	-2.22
CLIM 6	155.25	353.3	508.55	242.38	28.25	513.01	-4.46
CLIM 7	156.65	355.73	512.38	243.71	28.18	515.6	-3.22
CLIM 8	160.25	355.1	515.35	243.66	28.23	515.55	-0.2
CLIM 9	163.49	350.65	514.14	242.11	28.5	512.72	1.42
CLIM 10	163.98	345.31	509.29	239.61	28.98	508.2	1.09
CLIM 11	163.53	339.77	503.3	237.15	29.86	504.16	-0.86
CLIM 12	164.09	336.33	500.42	236.28	29.75	502.31	-1.89
average	162.35	345.15	507.50	239.62	29.00	508.23	-0.73

SFC (SW in + LW in) = 2OLR(all) + LWCRE (-0.73 W/m^2)

Stephens and L'Ecuyer 2015, Atmos Res
(my additions in white textboxes).
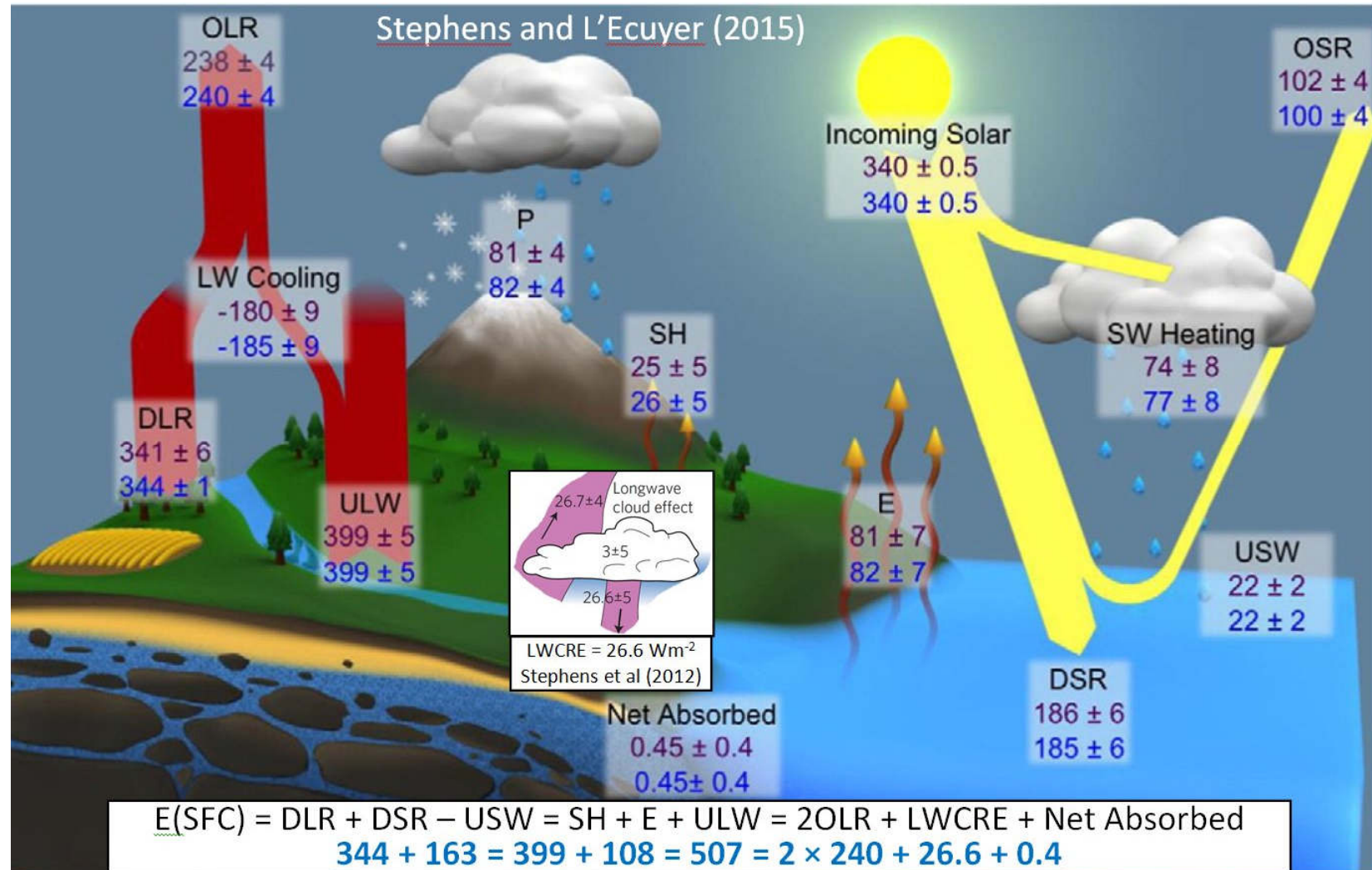
E(SFC, all) = LW in + SW in = 2OLR(all) + LWCRE + IMB - **0.05** (!!!) W/m²

344 + 163 = 2 x 240 + 26.6 + 0.45 - 0.05

All-sky, Ed2.8

All-sky	Ed2.8
TOA SW in	339.87
TOA SW up	99.62
TOA LW up	239.60
SFC SW down	186.47
SFC SW up	24.13
SFC SW in	162.34
SFC LW down	345.15
SFC SW + LW absorbed	507.49
SFC LW up	398.27
SFC Net	109.22
G	158.67
SFC LWCRE	28.88
2TOA LW Up + SFC LWCRE	508.08
Diff	−0.59

SFC energy in
(SW + LW) =
= 162.34 + 345.15
= **507.49**

=

2 x TOA LW out
+ SFC LWCRE
= 2 x 239.6 + 28.88
= **508.08**

Diff =
−0.59 W m^{-2}

Ed4.0

All-sky	Ed4.0
TOA SW in	340.04
TOA SW up	99.23
TOA LW up	240.14
SFC SW down	187.04
SFC SW up	23.37
SFC SW in	163.67
SFC LW down	344.97
SFC SW + LW absorbed	508.64
SFC LW up	398.34
SFC Net	110.30
G	158.20
SFC LWCRE	30.90
2TOA LW Up + SFC LWCRE	511.18
Diff	−2.54

All-sky, Ed4.0

Energy absorbed SFC
(W m^{-2}):

SW in + LW in =
163.67 + 344.97 =
508.64

2 x OLR + SFC LWCRE =
2 x 240.14 + 30.90 =
511.18

Diff = **−2.54 W m^{-2}**

Ed4.0

Clear-sky	Ed4.0
TOA SW in	340.04
TOA SW up	53.41
TOA LW up	268.13
SFC SW down	243.72
SFC SW up	29.81
SFC SW in	213.91
SFC LW down	314.07
SFC SW + LW Absorbed	527.98
SFC LW Up	397.59
SFC Net	130.39
G	129.46
Diff	0.93

Clear-sky, Ed4.0
SFC Net = G

SFC Net =
SW in + LW in − LW up
= 528.0 − 397.6
= **130.4** W m^{-2}

G = ULW − OLR =
397.6 − 268.1
= **129.5** W m^{-2}

Diff = **0.9** W m^{-2}.

Ed4.0

Clear-sky: SFC Net = G

G =SFC Net - Diff		ULW clear	OLR clear	G clear	SFC Net	Diff
CLIM 1		388.08	265.08	123	139.01	16.01
CLIM 2		389.63	265.27	124.36	137.49	13.13
CLIM 3		393.06	266.02	127.04	132.44	5.4
CLIM 4		397.64	267.04	130.6	126.25	-4.35
CLIM 5		402.18	268.99	133.19	121.41	-11.78
CLIM 6		405.9	271	134.9	122.11	-12.79
CLIM 7		407.29	272	135.29	124.59	-10.7
CLIM 8		406.4	271.71	134.69	127.49	-7.2
CLIM 9		402.83	270.36	132.47	129.98	-2.49
CLIM 10		397.57	268.14	129.43	132.33	2.9
CLIM 11		392	265.95	126.05	134.61	8.56
CLIM 12		388.69	264.91	123.78	137.19	13.41
Average		397.606	268.039	129.57	130.41	0.84

SFC Net = SW in + LW in − LW up = 213.9 + 314.1 − 397.6 = **130.4** W m^{-2}

G   = ULW − OLR   = 397.6 − 268.0   = **129.6** W m^{-2}

Diff =   = **0.8 W m^{-2}**

Pattern 5. All-sky integer ratios

Stephens et al. (2012)

Clear-sky emission
266.4±3.3
266.0 = **10**
Diff = 0.4 W/m²

Outgoing longwave radiation
239.7±3.3
239.4 = **9**
Diff = 0.3 W/m²

Longwave cloud effect

All-sky longwave absorption
-187.9±12.5
-186.2 = **-7**
Diff = 1.7 W/m²

26.7±4

3±5

26.6±5
26.6 = **1**

319±9 Clear-sky emission surface
319.2 = **12**
Diff = 0.2 W/m²

398±5
399.0 = **15**
Diff = 1.0 W/m²
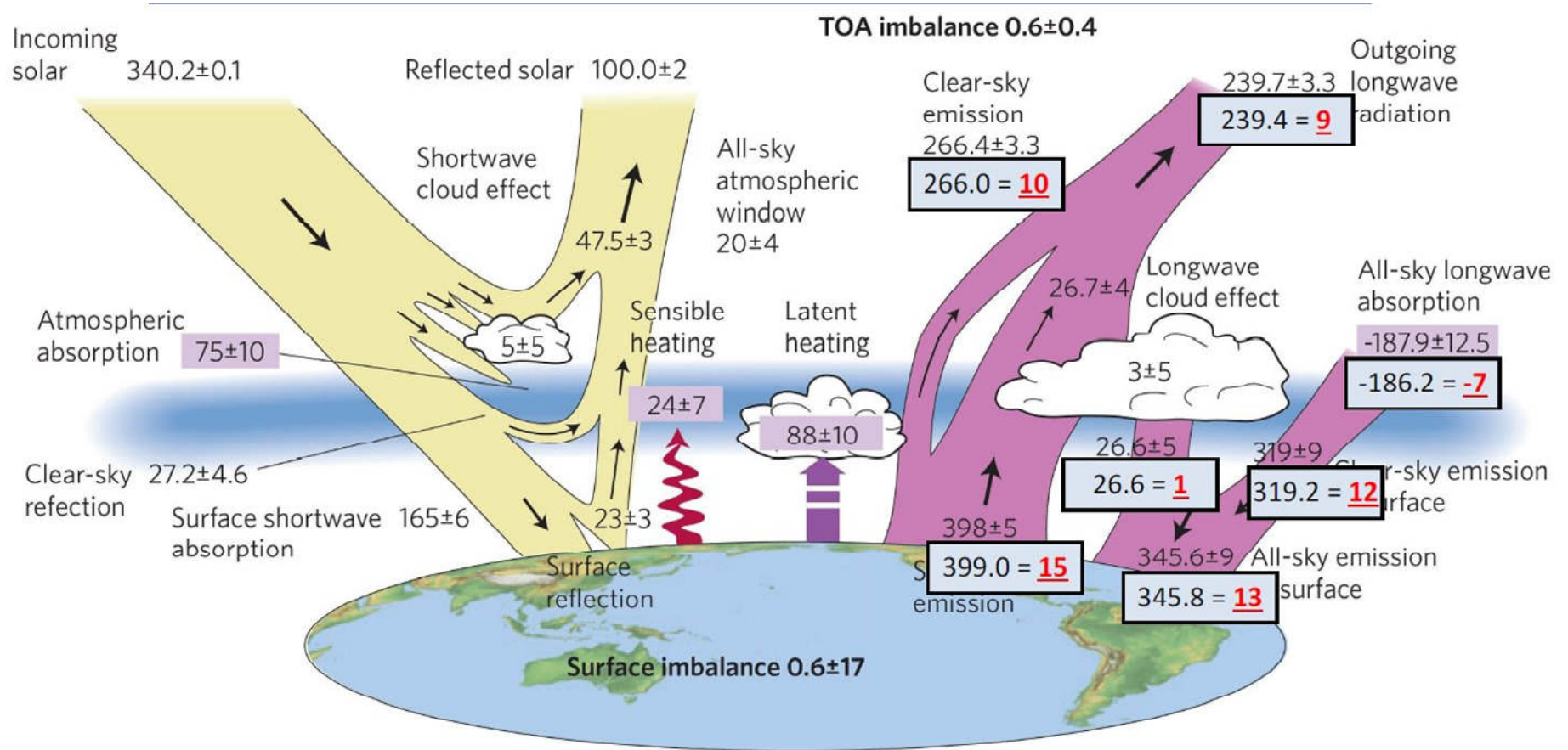
345.6±9 All-sky emission surface
345.8 = **13**
Diff = 0.2 W/m²
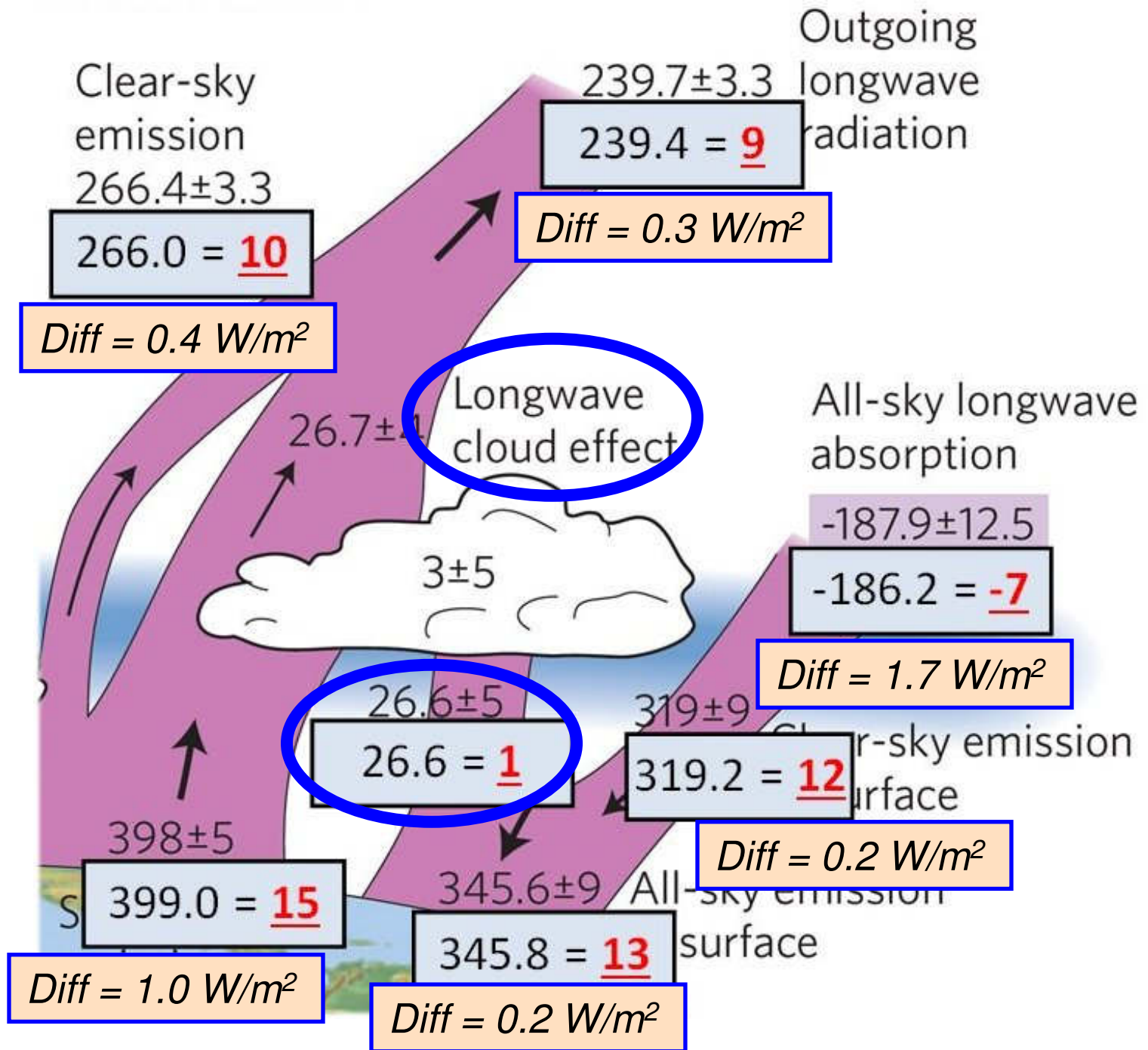
F = N × UNIT;   UNIT = OLR(all-sky)/9
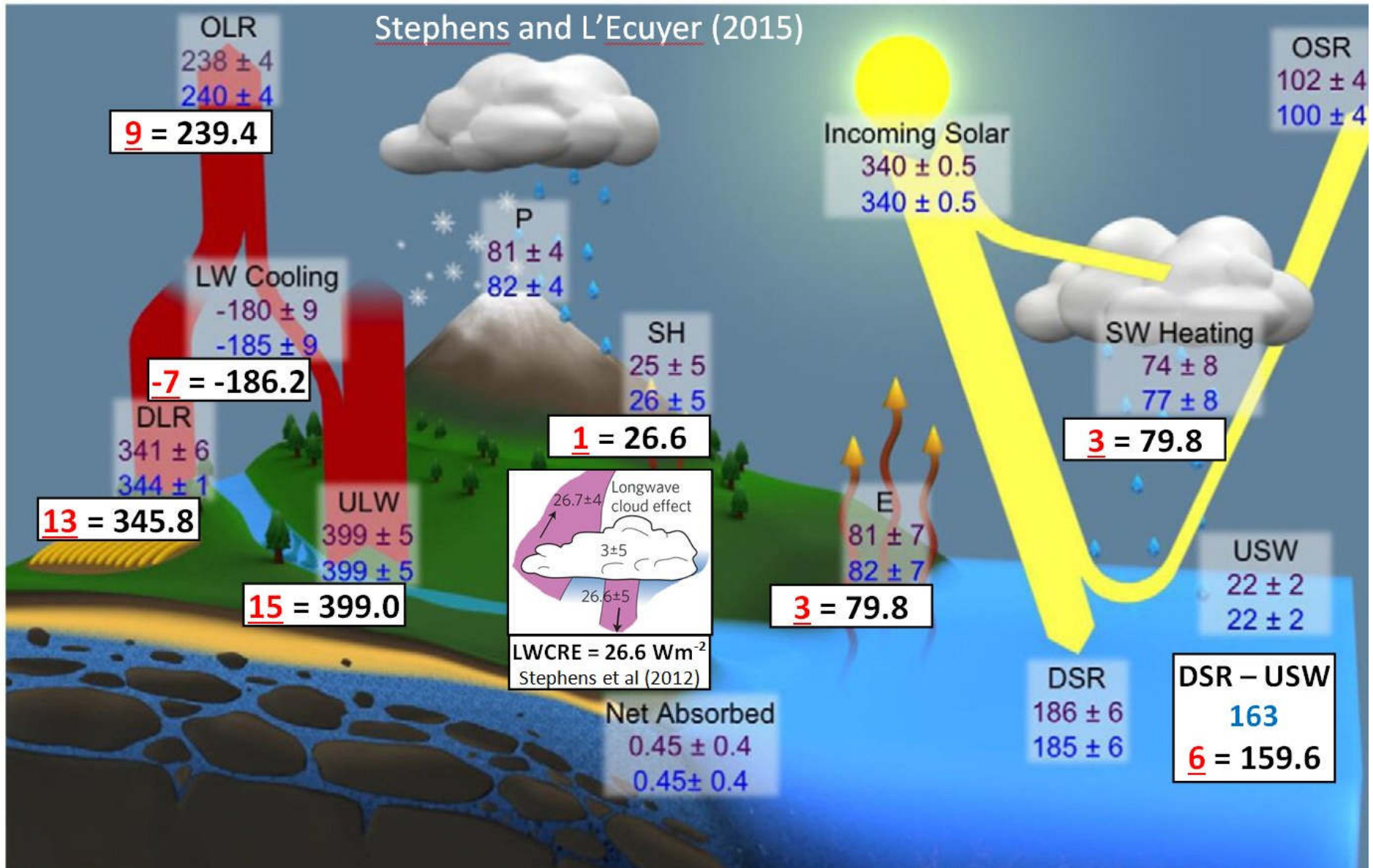
Is it possible
to satisfy all the patterns
with one data set?

Let's try.

Model data set: EdMZ
All-sky pattern positions

All-sky	Ed2.8	Ed4.0	EdMZ
TOA SW In	339.87	340.04	**340.04**
TOA SW Up	99.62	99.23	**99.60**
TOA LW Up	239.60	240.14	**240.14**
SFC SW In	162.34	163.67	**160.09**
SFC LW Down	345.15	344.97	**346.87**
SFC (SW in + LW in)	507.49	508.64	**506.96**
SFC LW Up	398.27	398.34	**400.23**
SFC Net	109.22	110.30	**106.73**
G	158.67	158.20	**160.09**
SFC LWCRE	28.88	30.90	**26.68**

Creating EdMZ, all-sky

All-sky	Ed4.0	⟶	EdMZ
TOA SW In	340.04	**0.0**	**340.04**
TOA SW Up	99.23		
TOA LW Up	240.14		
SFC SW In	163.67		
SFC LW Down	344.97		
SFC (SW in + LW in)	508.64		
SFC LW Up	398.34		
SFC Net	110.30		
G	158.20		
SFC LWCRE	30.90		

Creating EdMZ, all-sky

All-sky	Ed4.0	→	EdMZ
TOA SW In	340.04	**0.0**	**340.04**
TOA SW Up	99.23	**+0.37**	**99.60**
TOA LW Up	240.14		
SFC SW In	163.67		
SFC LW Down	344.97		
SFC (SW in + LW in)	508.64		
SFC LW Up	398.34		
SFC Net	110.30		
G	158.20		
SFC LWCRE	30.90		

Creating EdMZ, all-sky

All-sky	Ed4.0	→	EdMZ
TOA SW In	340.04	**0.0**	**340.04**
TOA SW Up	99.23	**+0.37**	**99.60**
TOA LW Up	240.14	**0.0**	**240.14**
SFC SW In	163.67		
SFC LW Down	344.97		
SFC (SW in + LW in)	508.64		
SFC LW Up	398.34		
SFC Net	110.30		
G	158.20		
SFC LWCRE	30.90		

Creating EdMZ, all-sky

All-sky	Ed4.0	→	EdMZ
TOA SW In	340.04	**0.0**	**340.04**
TOA SW Up	99.23	**+0.37**	**99.60**
TOA LW Up	240.14	**0.0**	**240.14**
SFC SW In	163.67	**-3.58**	**160.09**
SFC LW Down	344.97		
SFC (SW in + LW in)	508.64		
SFC LW Up	398.34		
SFC Net	110.30		
G	158.20		
SFC LWCRE	30.90		

Creating EdMZ, all-sky

All-sky	Ed4.0	→	EdMZ
TOA SW In	340.04	**0.0**	**340.04**
TOA SW Up	99.23	**+0.37**	**99.60**
TOA LW Up	240.14	**0.0**	**240.14**
SFC SW In	163.67	**-3.58**	**160.09**
SFC LW Down	344.97	**+1.90**	**346.87**
SFC (SW in + LW in)	508.64		
SFC LW Up	398.34		
SFC Net	110.30		
G	158.20		
SFC LWCRE	30.90		

Creating EdMZ, all-sky

All-sky	Ed4.0	➡	EdMZ
TOA SW In	340.04	**0.0**	**340.04**
TOA SW Up	99.23	**+0.37**	**99.60**
TOA LW Up	240.14	**0.0**	**240.14**
SFC SW In	163.67	**-3.58**	**160.09**
SFC LW Down	344.97	**+1.90**	**346.87**
SFC (SW in + LW in)	508.64	**-1.71**	**506.96**
SFC LW Up	398.34		
SFC Net	110.30		
G	158.20		
SFC LWCRE	30.90		

Creating EdMZ, all-sky

All-sky	Ed4.0	→	EdMZ
TOA SW In	340.04	**0.0**	**340.04**
TOA SW Up	99.23	**+0.37**	**99.60**
TOA LW Up	240.14	**0.0**	**240.14**
SFC SW In	163.67	**-3.58**	**160.09**
SFC LW Down	344.97	**+1.90**	**346.87**
SFC (SW in + LW in)	508.64	**-1.71**	**506.96**
SFC LW Up	398.34	**+1.89**	**400.23**
SFC Net	110.30		
G	158.20		
SFC LWCRE	30.90		

Creating EdMZ, all-sky

All-sky	Ed4.0	→	EdMZ
TOA SW In	340.04	0.0	340.04
TOA SW Up	99.23	+0.37	99.60
TOA LW Up	240.14	0.0	240.14
SFC SW In	163.67	-3.58	160.09
SFC LW Down	344.97	+1.90	346.87
SFC (SW in + LW in)	508.64	-1.71	506.96
SFC LW Up	398.34	+1.89	400.23
SFC Net	110.30	-3.57	106.73
G	158.20		
SFC LWCRE	30.90		

Creating EdMZ, all-sky

All-sky	Ed4.0	→	EdMZ
TOA SW In	340.04	0.0	340.04
TOA SW Up	99.23	+0.37	99.60
TOA LW Up	240.14	0.0	240.14
SFC SW In	163.67	-3.58	160.09
SFC LW Down	344.97	+1.90	346.87
SFC (SW in + LW in)	508.64	-1.71	506.96
SFC LW Up	398.34	+1.89	400.23
SFC Net	110.30	-3.57	106.73
G	158.20	+1.89	160.09
SFC LWCRE	30.90		

Creating EdMZ, all-sky

All-sky	Ed4.0	→	EdMZ
TOA SW In	340.04	0.0	340.04
TOA SW Up	99.23	+0.37	99.60
TOA LW Up	240.14	0.0	240.14
SFC SW In	163.67	-3.58	160.09
SFC LW Down	344.97	+1.90	346.87
SFC (SW in + LW in)	508.64	-1.71	506.96
SFC LW Up	398.34	+1.89	400.23
SFC Net	110.30	-3.57	106.73
G	158.20	+1.89	160.09
SFC LWCRE	30.90	-4.22	26.68

EdMZ all-sky integer ratios
F = N × UNIT
UNIT = OLR(all-sky)/9

All-sky Flux	EdMZ	N
TOA SW In	340.04	
TOA SW Up	99.60	
TOA LW Up	240.14	9
SFC SW In	160.09	6
SFC LW Down	346.87	13
SFC (SW in + LW in)	506.96	19
SFC LW Up	400.23	15
SFC Net	106.73	4
G	160.09	6
SFC LWCRE	26.68	1
2 × TOA LW Up + LWCRE	506.96	19

Model data set: EdMZ
Clear-sky pattern positions

Clear-sky	Ed2.8	Ed4.0	EdMZ
TOA SW in	339.87	340.04	**340.04**
TOA LW up	265.59	268.13	**266.82**
SFC SW in	214.32	213.91	**213.47**
SFC LW down	316.27	314.07	**320.18**
SFC (SW + LW) in	530.59	527.98	**533.65**
SFC LW up	398.40	397.59	**400.23**
SFC Net	132.19	130.39	**133.42**
G	132.81	129.46	**133.42**
TOA LWCRE	25.99	27.99	**26.68**

Creating EdMZ, clear-sky

Clear-sky	Ed4.0	→	EdMZ
TOA SW In	340.04	**0.0**	**340.04**
TOA LW Up	268.13		
SFC SW In	213.91		
SFC LW Down	314.07		
SFC (SW + LW) In	527.98		
SFC LW Up	397.59		
SFC Net	130.39		
G	129.46		
TOA LWCRE	27.99		

Creating EdMZ, clear-sky

Clear-sky	Ed4.0	→	EdMZ
TOA SW In	340.04	**0.0**	**340.04**
TOA LW Up	268.13	**-1.31**	**266.82**
SFC SW In	213.91		
SFC LW Down	314.07		
SFC (SW + LW) In	527.98		
SFC LW Up	397.59		
SFC Net	130.39		
G	129.46		
TOA LWCRE	27.99		

Creating EdMZ, clear-sky

Clear-sky	Ed4.0	⟶	EdMZ
TOA SW In	340.04	**0.0**	**340.04**
TOA LW Up	268.13	**-1.31**	**266.82**
SFC SW In	213.91	**-0.44**	**213.47**
SFC LW Down	314.07		
SFC (SW + LW) In	527.98		
SFC LW Up	397.59		
SFC Net	130.39		
G	129.46		
TOA LWCRE	27.99		

Creating EdMZ, clear-sky

Clear-sky	Ed4.0	→	EdMZ
TOA SW In	340.04	0.0	340.04
TOA LW Up	268.13	-1.31	266.82
SFC SW In	213.91	-0.44	213.47
SFC LW Down	314.07	+6.11	320.18
SFC (SW + LW) In	527.98		
SFC LW Up	397.59		
SFC Net	130.39		
G	129.46		
TOA LWCRE	27.99		

Creating EdMZ, clear-sky

Clear-sky	Ed4.0	⟶	EdMZ
TOA SW In	340.04	**0.0**	**340.04**
TOA LW Up	268.13	**-1.31**	**266.82**
SFC SW In	213.91	**-0.44**	**213.47**
SFC LW Down	314.07	**+6.11**	**320.18**
SFC (SW + LW) In	527.98	**+5.87**	**533.65**
SFC LW Up	397.59		
SFC Net	130.39		
G	129.46		
TOA LWCRE	27.99		

Creating EdMZ, clear-sky

Clear-sky	Ed4.0	⟹	EdMZ
TOA SW In	340.04	0.0	340.04
TOA LW Up	268.13	-1.31	266.82
SFC SW In	213.91	-0.44	213.47
SFC LW Down	314.07	+6.11	320.18
SFC (SW + LW) In	527.98	+5.87	533.65
SFC LW Up	397.59	+2.64	400.23
SFC Net	130.39		
G	129.46		
TOA LWCRE	27.99		

Creating EdMZ, clear-sky

Clear-sky	Ed4.0	⟶	EdMZ
TOA SW In	340.04	**0.0**	**340.04**
TOA LW Up	268.13	**-1.31**	**266.82**
SFC SW In	213.91	**-0.44**	**213.47**
SFC LW Down	314.07	**+6.11**	**320.18**
SFC (SW + LW) In	527.98	**+5.87**	**533.65**
SFC LW Up	397.59	**+2.64**	**400.23**
SFC Net	130.39	**+3.03**	**133.42**
G	129.46		
TOA LWCRE	27.99		

Creating EdMZ, clear-sky

Clear-sky	Ed4.0	→	EdMZ
TOA SW In	340.04	**0.0**	**340.04**
TOA LW Up	268.13	**-1.31**	**266.82**
SFC SW In	213.91	**-0.44**	**213.47**
SFC LW Down	314.07	**+6.11**	**320.18**
SFC (SW + LW) In	527.98	**+5.87**	**533.65**
SFC LW Up	397.59	**+2.64**	**400.23**
SFC Net	130.39	**+3.03**	**133.42**
G	129.46	**+3.96**	**133.42**
TOA LWCRE	27.99		

Creating EdMZ, clear-sky

Clear-sky	Ed4.0	→	EdMZ
TOA SW In	340.04	0.0	340.04
TOA LW Up	268.13	-1.31	266.82
SFC SW In	213.91	-0.44	213.47
SFC LW Down	314.07	+6.11	320.18
SFC (SW + LW) In	527.98	+5.87	533.65
SFC LW Up	397.59	+2.64	400.23
SFC Net	130.39	+3.03	133.42
G	129.46	+3.96	133.42
TOA LWCRE	27.99	-1.31	26.68

EdMZ clear-sky integer ratios
F = N × UNIT
UNIT = OLR(clear-sky)/4

Clear-sky Flux	EdMZ	N
TOA SW In	340.04	
TOA LW Up	266.82	4
ATM emitted Up	200.11	3
STI	66.7	1
SFC (SW + LW) In	533.65	8
SFC LW Up	400.23	6
SFC Net	133.42	2
G	133.42	2

Clear-sky fluxes in all-sky units
$F = N \times \text{UNIT(all-sky)}$

Clear-sky Flux	EdMZ	N
TOA SW In	340.04	
TOA LW Up	266.82	10
SFC SW In	213.47	8
SFC LW Down	320.18	12
SFC (SW + LW) In	533.65	20
SFC LW Up	400.23	15
SFC Net	133.42	5
G	133.42	5
TOA LWCRE (UNIT)	26.68	1

The patterns as integers

- P1 (clear-sky):   SFC (SW + LW) (in) $= 2 \times$ OLR
$$8 + 12 \qquad\qquad = 2 \times 10$$

- P2 (clear-sky):   SFC Net = ULW − OLR   = G
$$20 - 15 = 15 - 10 \qquad = 5$$
$$8 - 6 = 6 - 4 \qquad = 2$$

- P3 (clear-sky): STI / G / ATM / OLR / ULW / E(SFC)
$$1 \ / \ 2 \ / \ 3 \ / \ 4 \ / \ 6 \ / \ 8$$

- P4 (all-sky): SFC (SW + LW) (in) $= 2 \times$ OLR + LWCRE
$$6 + 13 \qquad = 2 \times 9 + 1$$

- P5 (all-sky): F = **N** × UNIT, UNIT = OLR(all-sky) / 9.

CLEAR SKY basics: g = (15 − 10) /15 = **5/15** = 1/3

ALL SKY basics: g = (15 − 9) /15 = **6/15** = 0.4

213.3
8

240
9

26.7
1

160
6

347
13

400
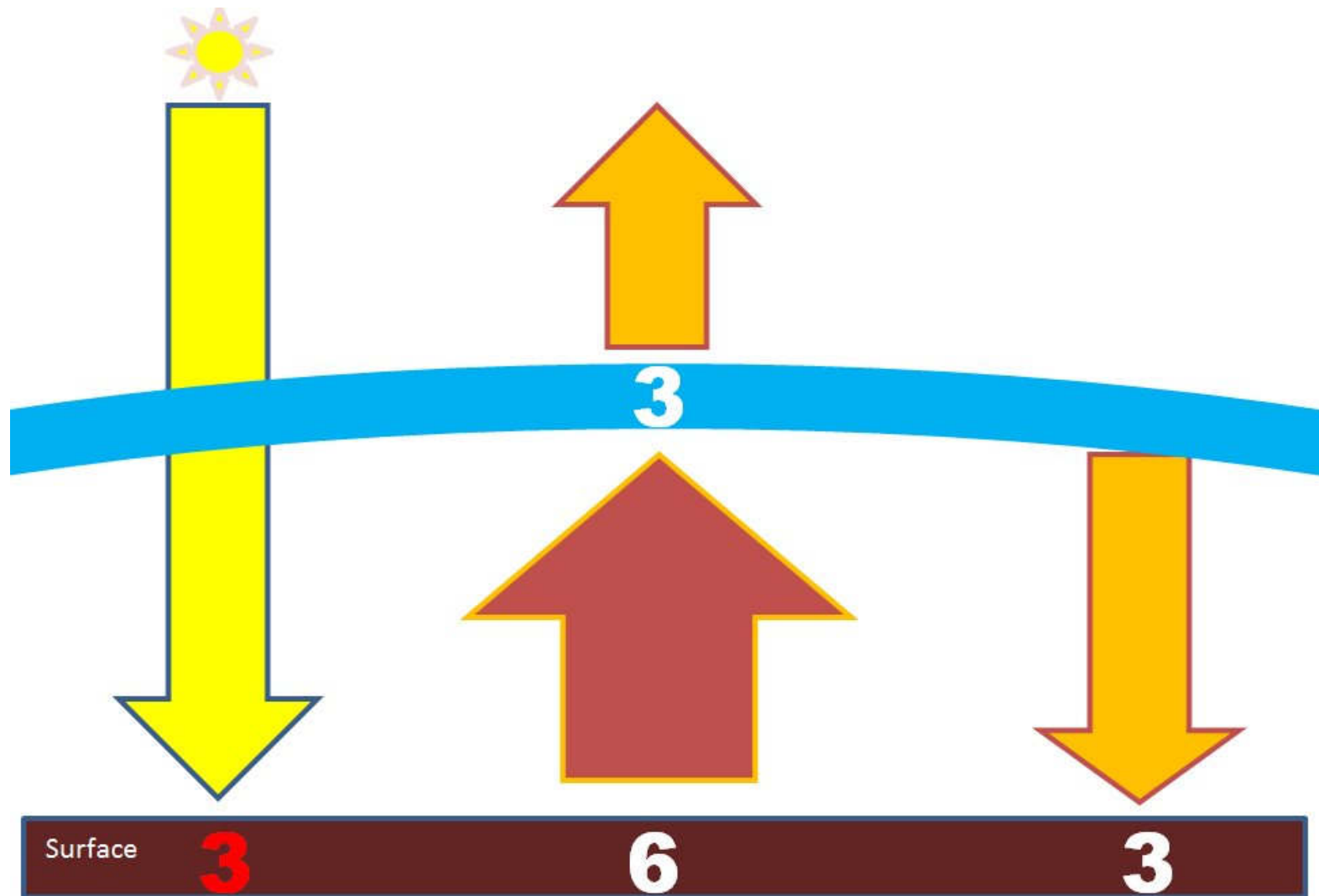**15**

507
19

107
4
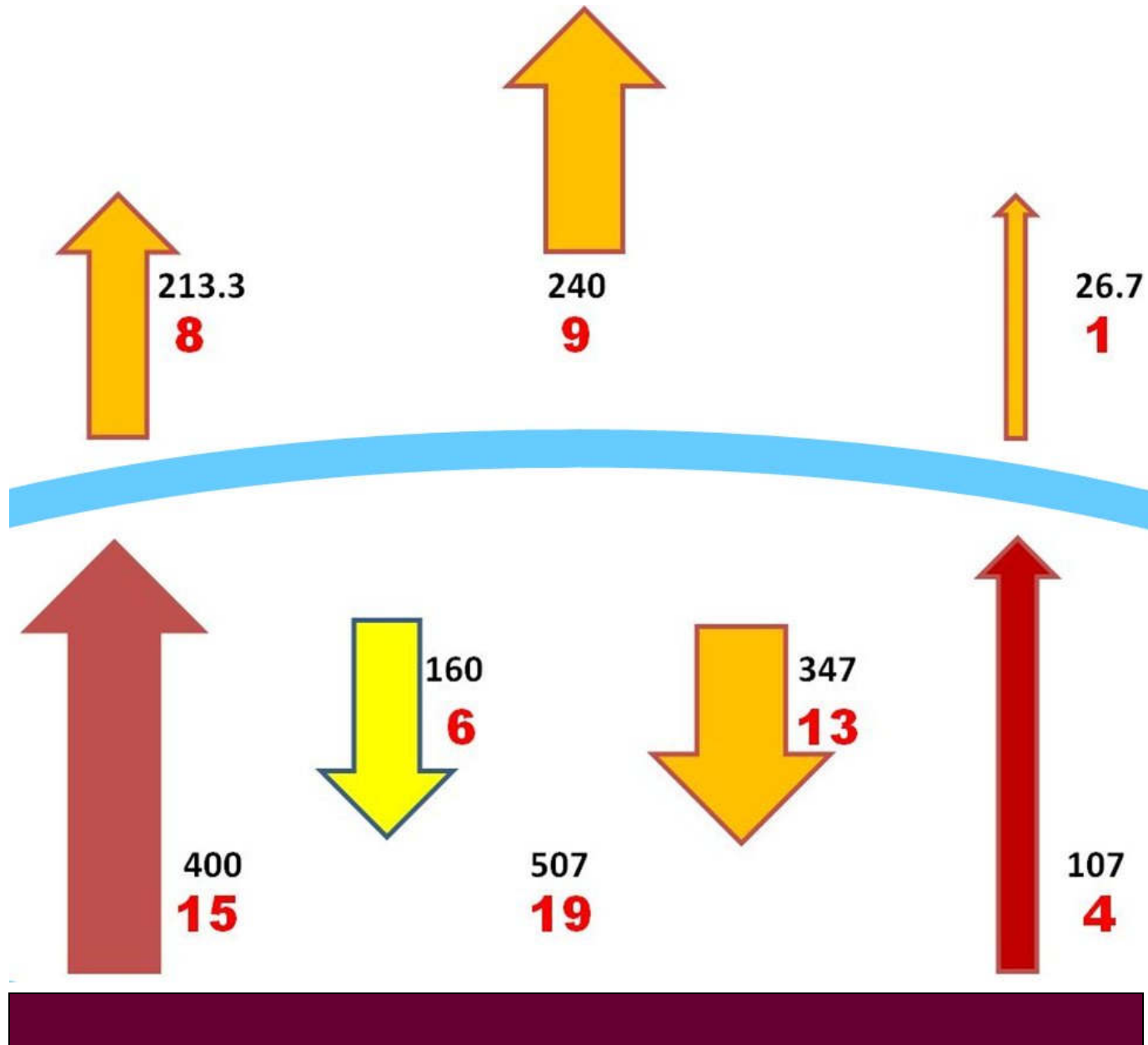
Deduction of EdMZ
from the Closed Shell Geometry

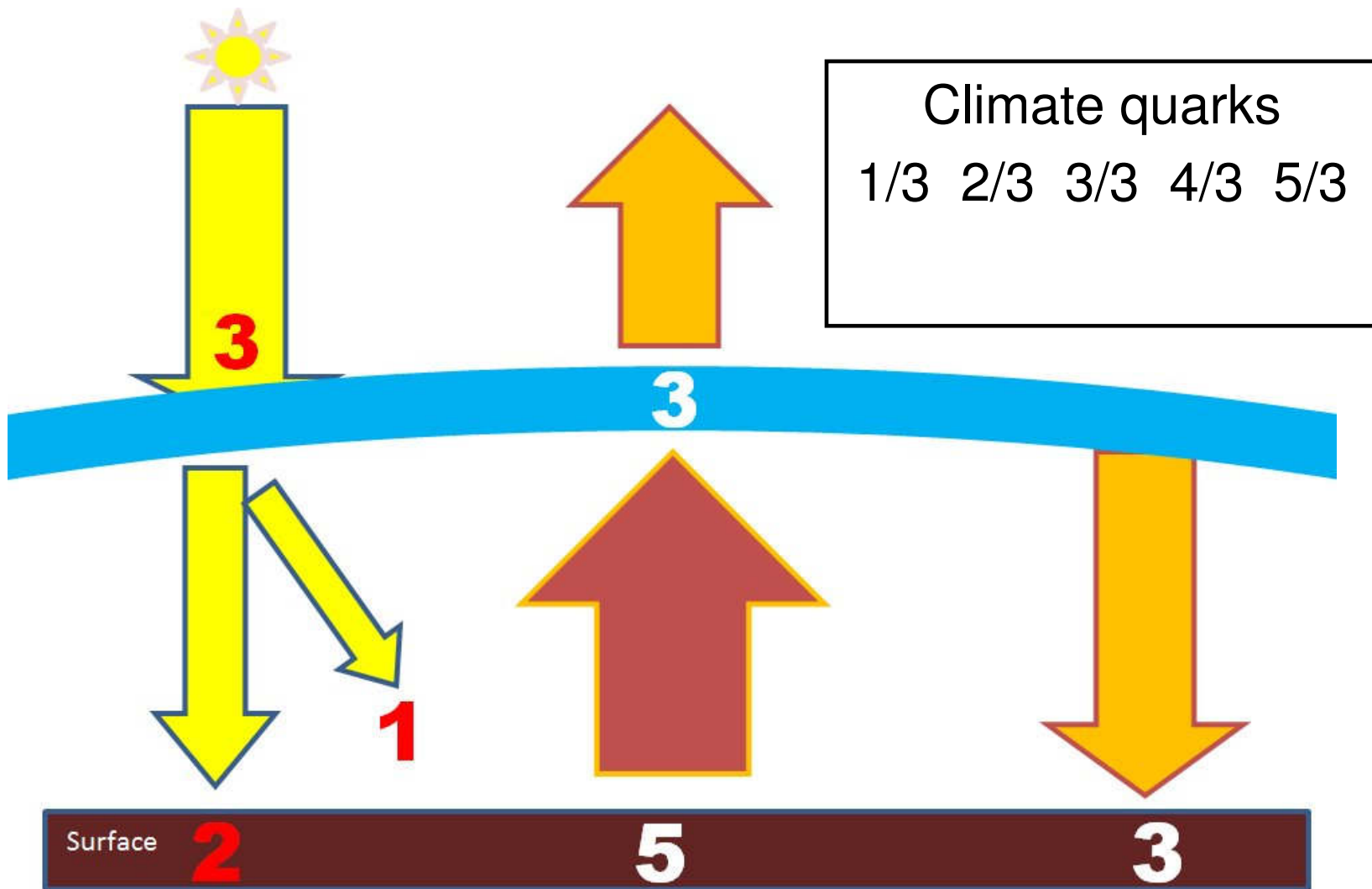**Step 0** *Starting point*: SW-transparent, LW-opaque, non-turbulent
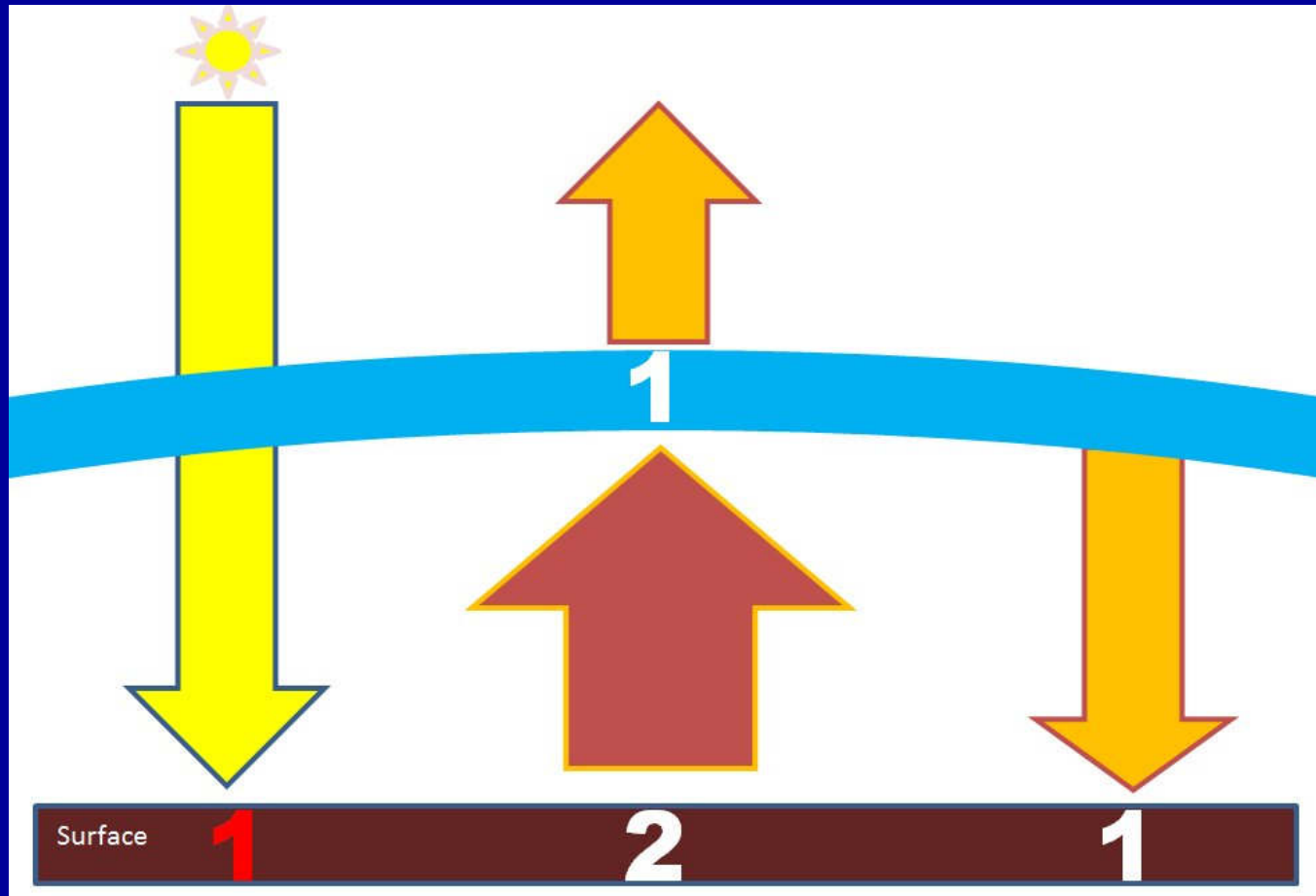
Solar Absorbed Surface (SAS) = 1 goes into G = ULW – OLR = 1

Step 1 *Unit change*: 1 => 3

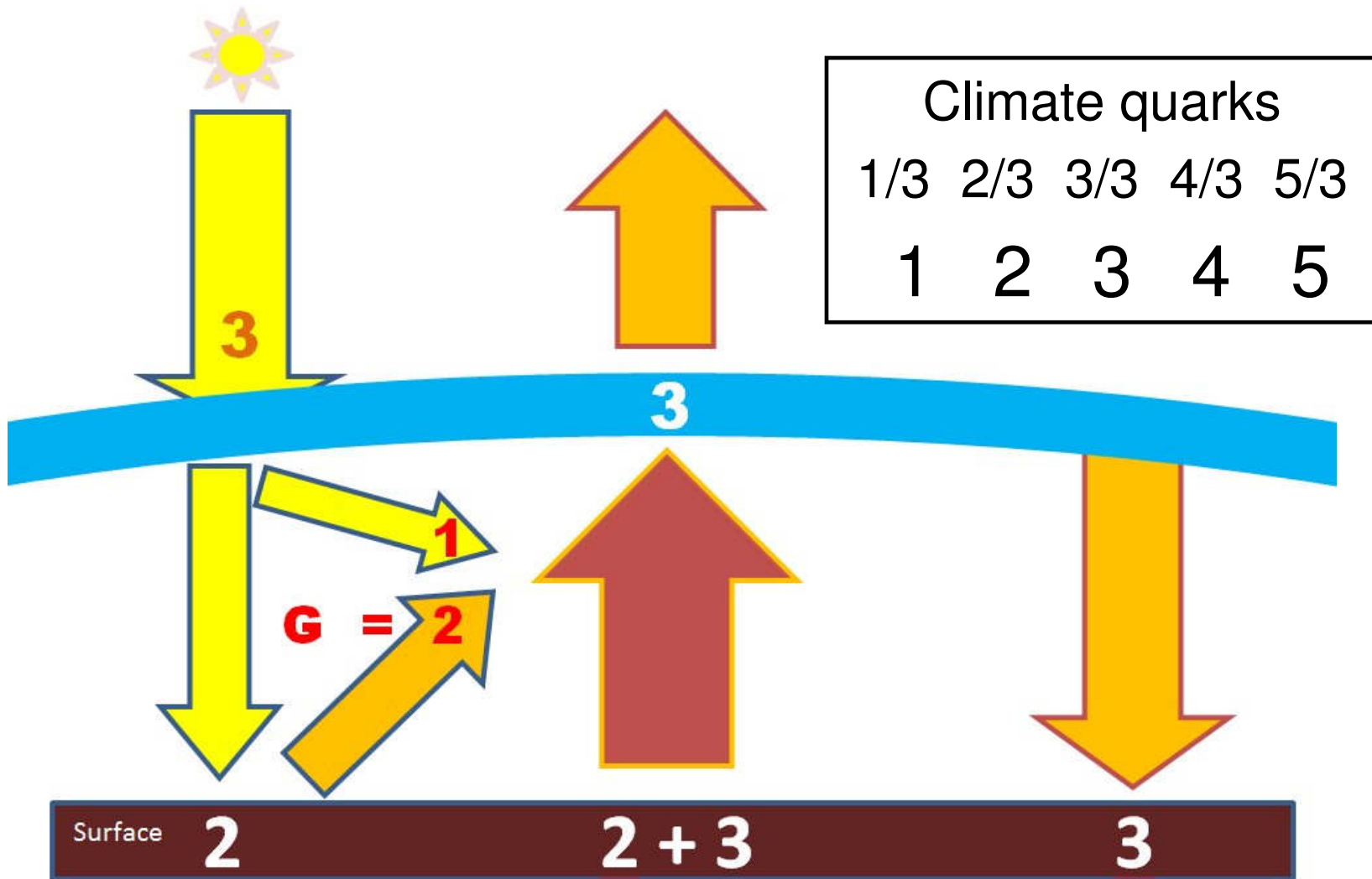Solar Absorbed Surface (SAS) = 3 goes into G = ULW – OLR = 3

Step 2 *Allow* **ONE** *atmospheric SW-absorption: SAA = 1, SAS = 2*

Climate quarks

1/3 2/3 3/3 4/3 5/3

Solar Absorbed Atmosphere (SAA) = 1, Solar Absorbed Surface (SAS) = 2

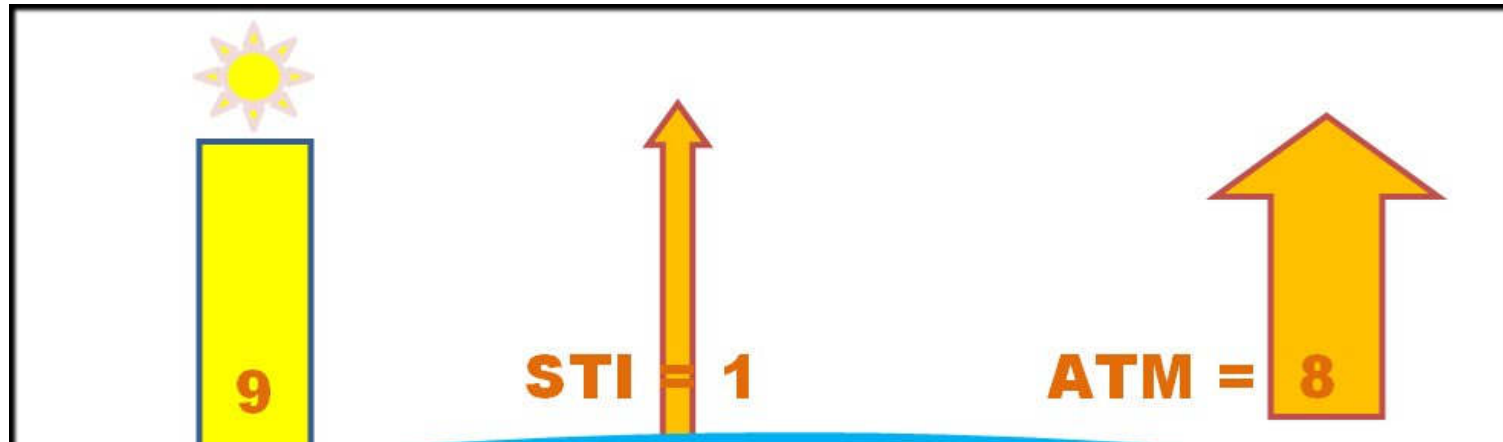**Step 3** *Solar Absorbed Surface (SAS = 2) goes into* **G** *= ULW − OLR = 2*

Climate quarks

1/3 2/3 3/3 4/3 5/3

1   2   3   4   5

G = 2

3

3

3

1

Surface 2   2 + 3   3

'SAS = G' property kept

Step 4 *Unit change: 3 => 9.*
Solar Absorbed Surface (SAS = 6) goes into **G** *= ULW − OLR = 6*

Climate quarks

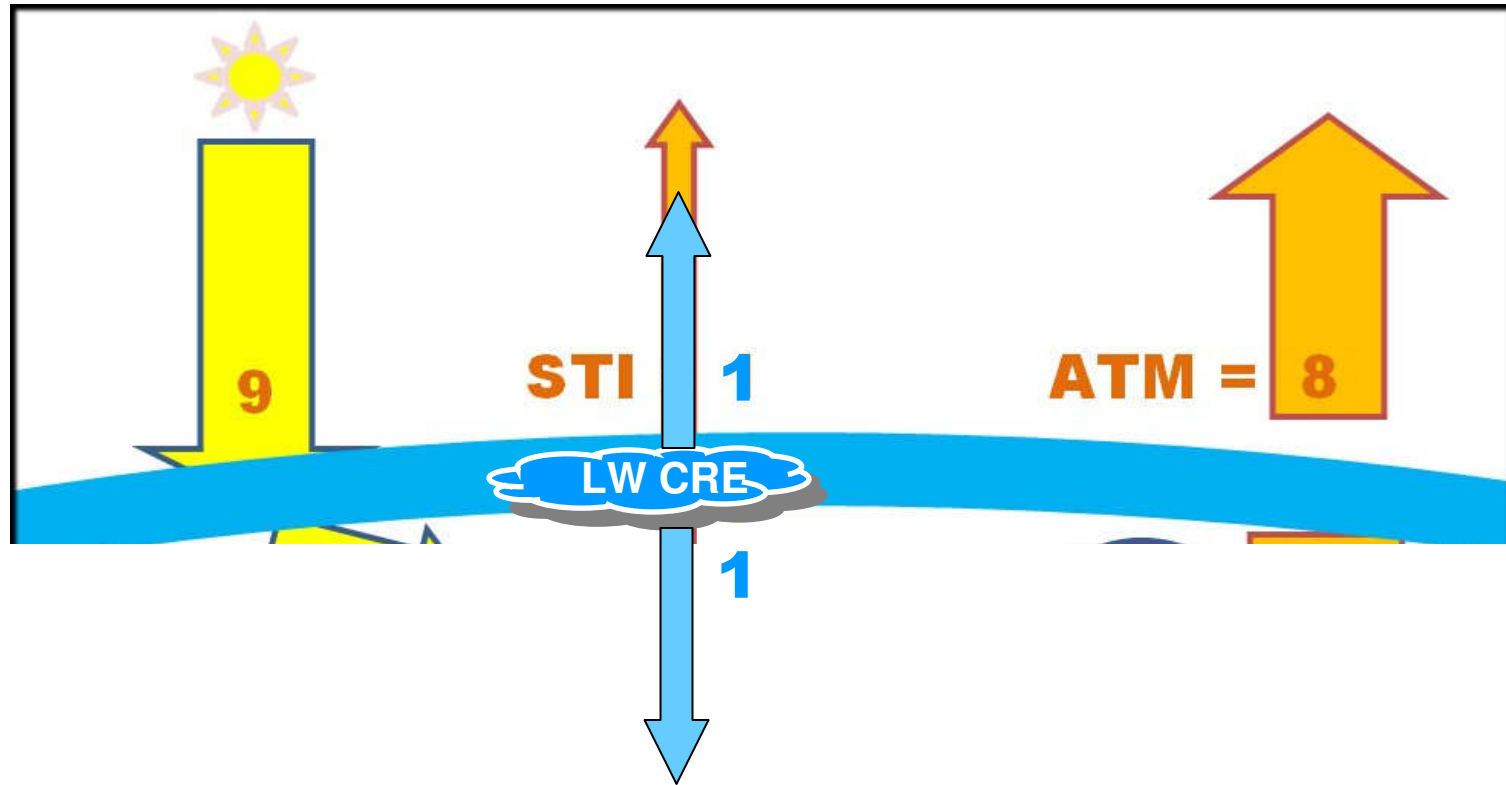| 1/3	2/3	3/3	4/3	5/3
3	6	9	12	15

9

9

3

G = 6

Surface 6   6 + 9   9
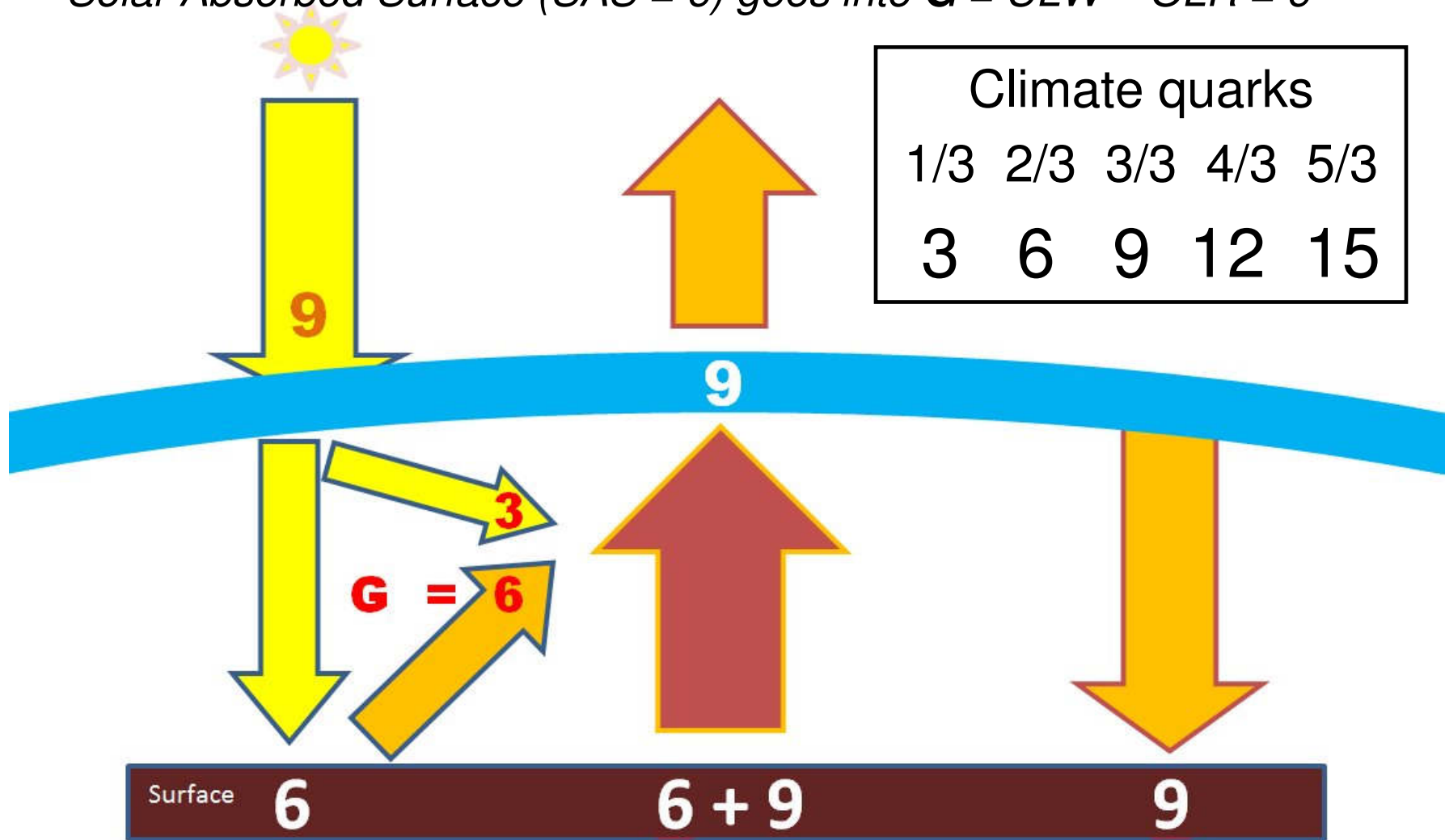
SAS (6) = G (6)
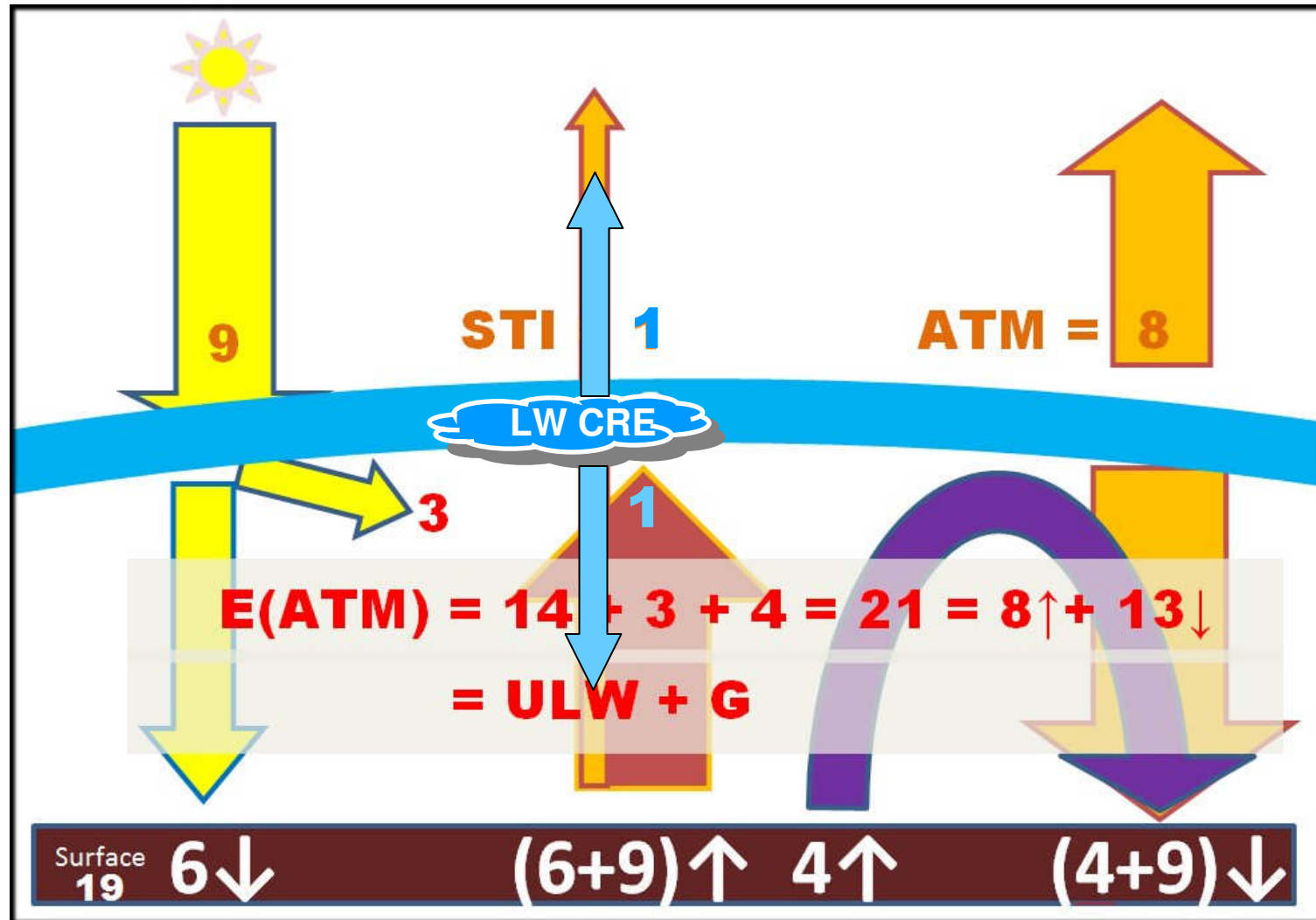
Step 5 *Allow **ONE** partial LW-transparency …*

Step 6 … *fade the window with* **ONE** *up and down LW cloud effect*

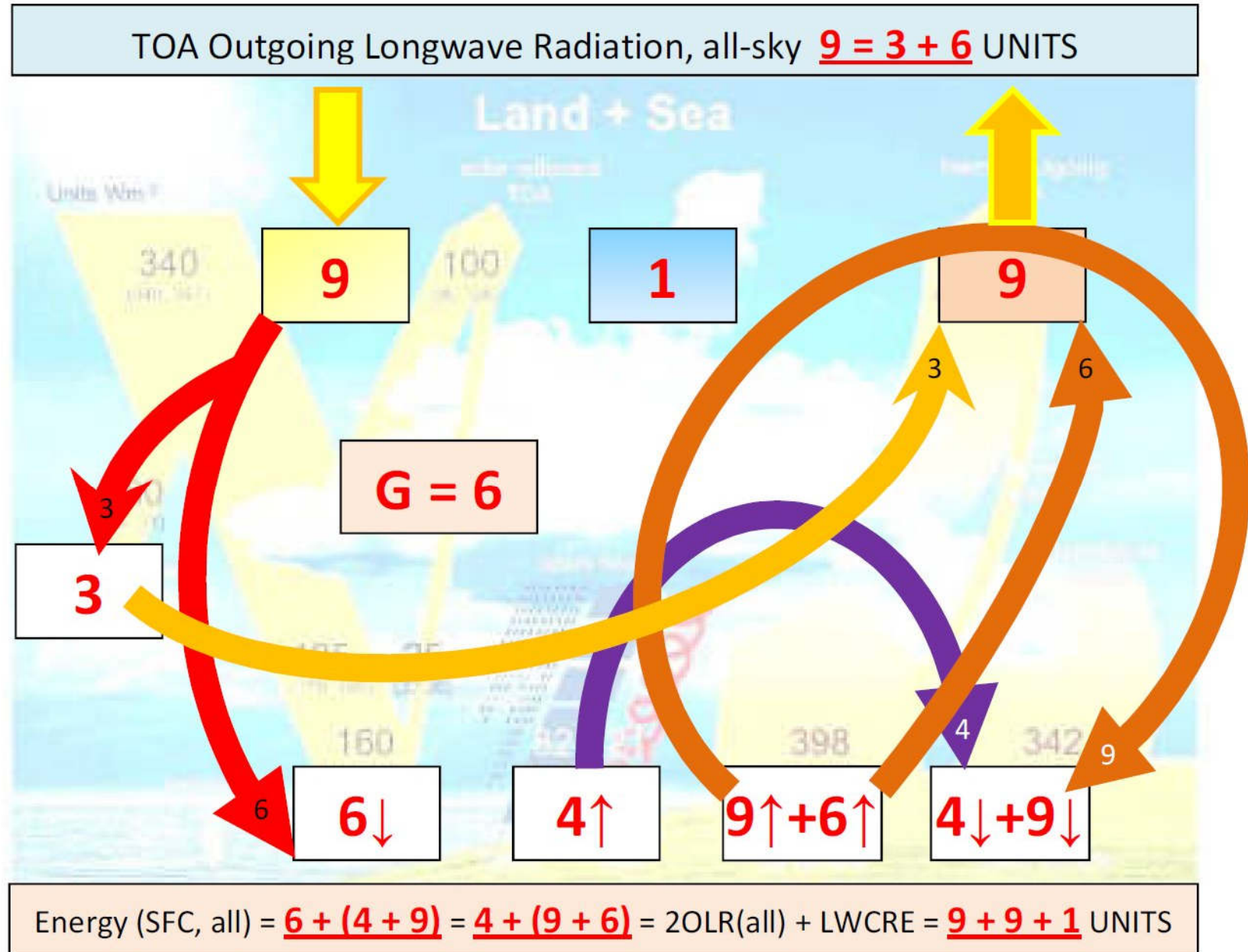# Step 7 … and close the balance with turbulence.
Atmosphere: E(SFC) + **2** UNITS = **21** = emitted up (**8**) + down (**13**)

Surface: E(SFC) = **2** OLR + **1** UNIT = **19**

The pattern. *Basic energy flow routes and integer rates.*

TOA Outgoing Longwave Radiation, all-sky **9 = 3 + 6** UNITS

Land + Sea

9

1

9

3   6

G = 6

3

3

4

9

6   6↓

4↑

9↑+6↑

4↓+9↓

Energy (SFC, all) = **6 + (4 + 9)** = **4 + (9 + 6)** = 2OLR(all) + LWCRE = **9 + 9 + 1** UNITS

EdMZ all-sky integer ratios
F = N × UNIT
UNIT = OLR(all-sky)/9

All-sky Flux	EdMZ	N
TOA SW In	340.04	
TOA SW Up	99.60	
TOA LW Up	240.14	9
SFC SW In	160.09	6
SFC LW Down	346.87	13
SFC (SW in + LW in)	506.96	19
SFC LW Up	400.23	15
SFC Net	106.73	4
G	160.09	6
SFC LWCRE	26.68	1
2 × TOA LW Up + LWCRE	506.96	19

TOA Outgoing Longwave Radiation, all-sky **9 = 3 + 6** UNITS

Land + Sea

9

1

9

G = 6

3

3

6↓   **4↑**   **9↑+6↑**   **4↓+9↓**

Energy (SFC, all) = **6 + (4 + 9)** = **4 + (9 + 6)** = 2OLR(all) + LWCRE = **9 + 9 + 1** UNITS
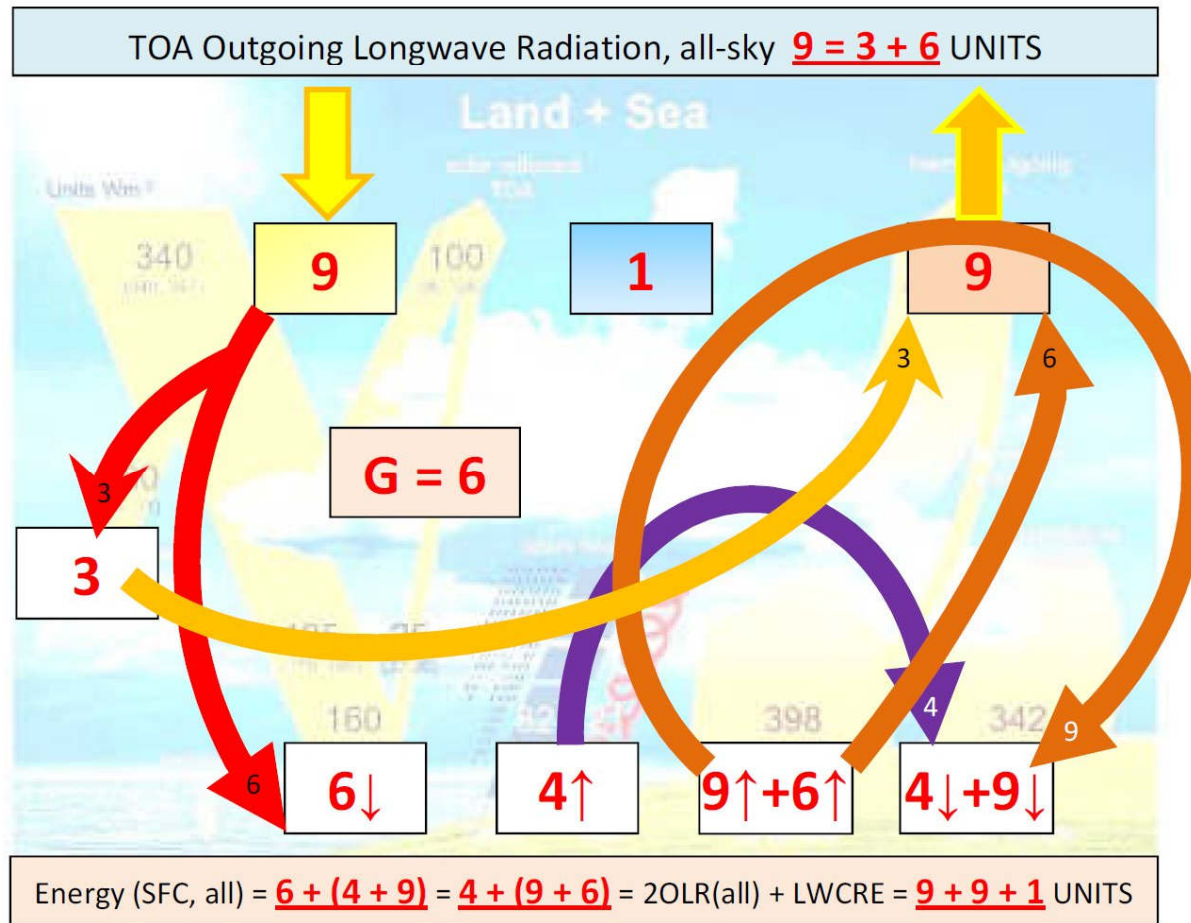
ASR = OLR = **9** = 240, SAA = **3** = 80, SAS = **6** = 160
ULW = **15** = 400, G = **6** = 160, SFC Net = **4** = 107
DLR = **13** = 346, LW Cooling = **-7** = -187
1 = UNIT = 26.68 (W m^{-2})

Loeb (2015)
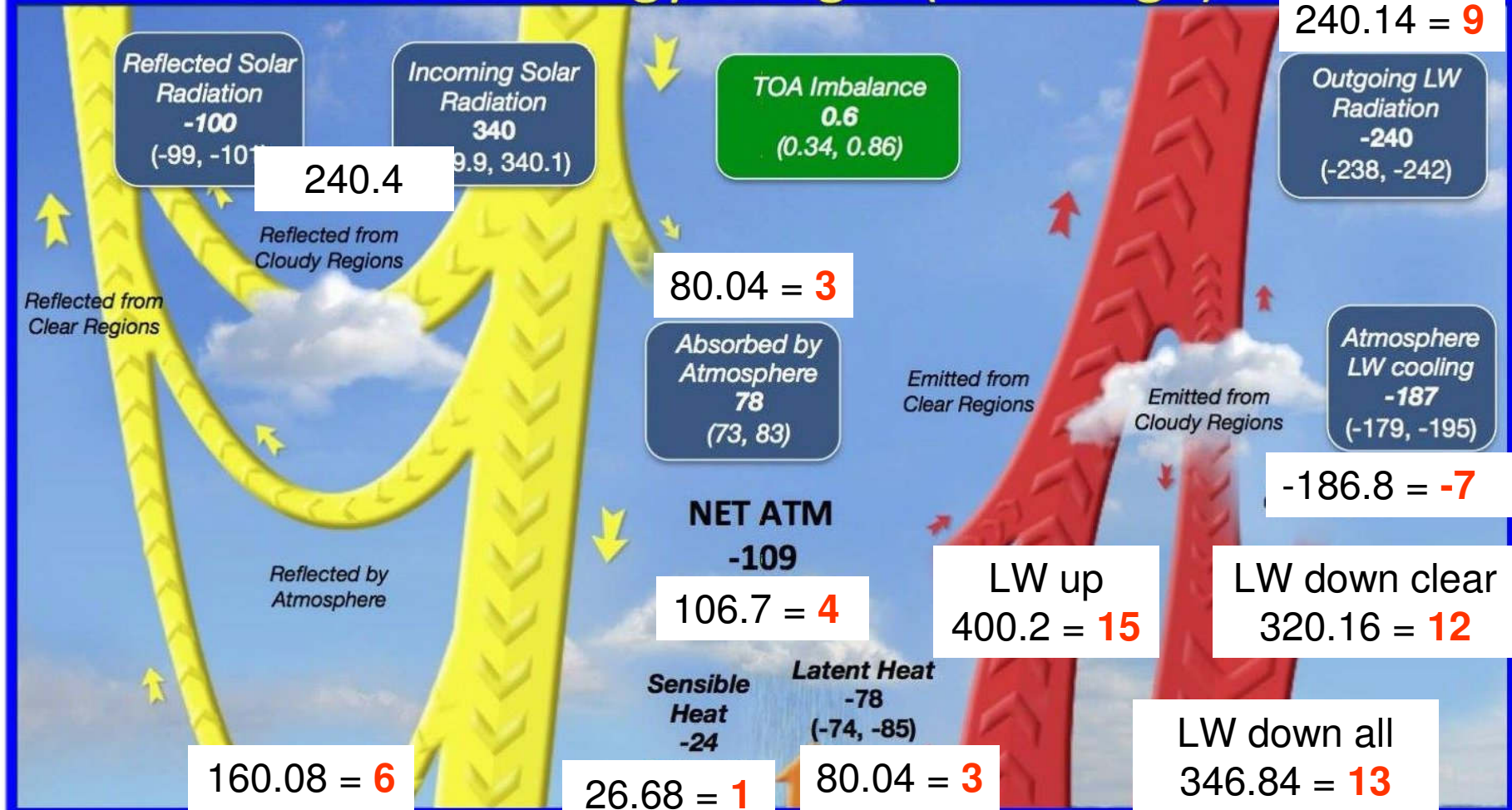
EdMZ with ISR = 340.0 and OLR = 240.1 Wm^{-2}
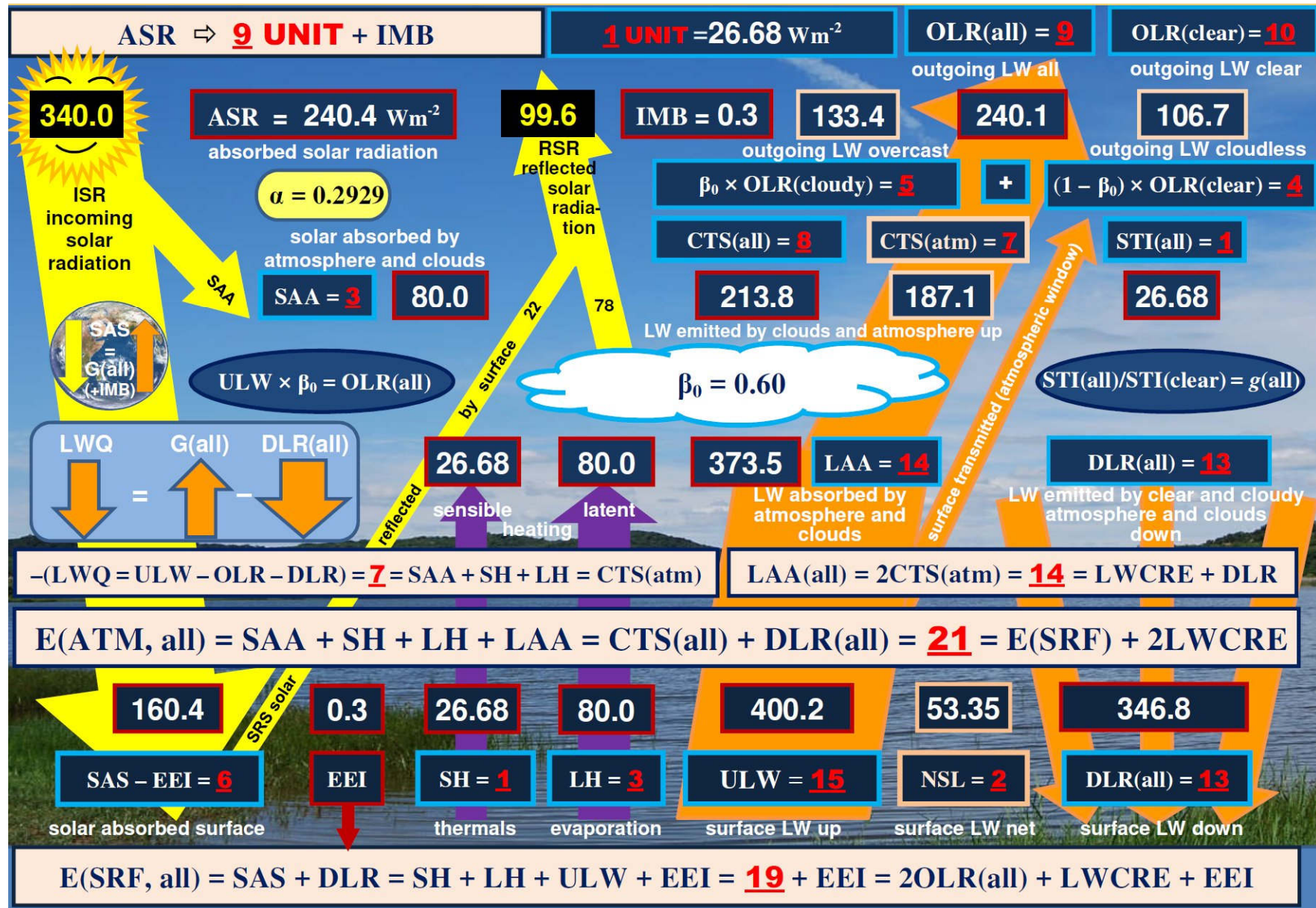
Specific geometries

Moon (zero)		
ULW − G = OLR	G = 0	g = 0
ULW + G = OLR	ULW = OLR	t = 1

Mars (intermediate, free)		
ULW − G = OLR	G = 0.118 OLR	g = 0.106
ULW + G = 1.236 OLR	ULW = 1.118 OLR	t = 0.732

Earth (clear-sky) (level one)		
ULW − G = OLR	G = (1/2) OLR	g = 1/3
ULW + G = 2OLR	ULW = (3/2) OLR	t = 1/6

Earth (all-sky) (level two)		
ULW − G = OLR	G = (2/3) OLR	g = 2/5
ULW + G = (7/3) OLR	ULW = (5/3) OLR	t = 1/15

Shield (level three)		
ULW − G = OLR	G = OLR	g = 1/2
ULW + G = 3OLR	ULW = 2OLR	t = 0

t = STI/ULW, atmospheric LW transmittance
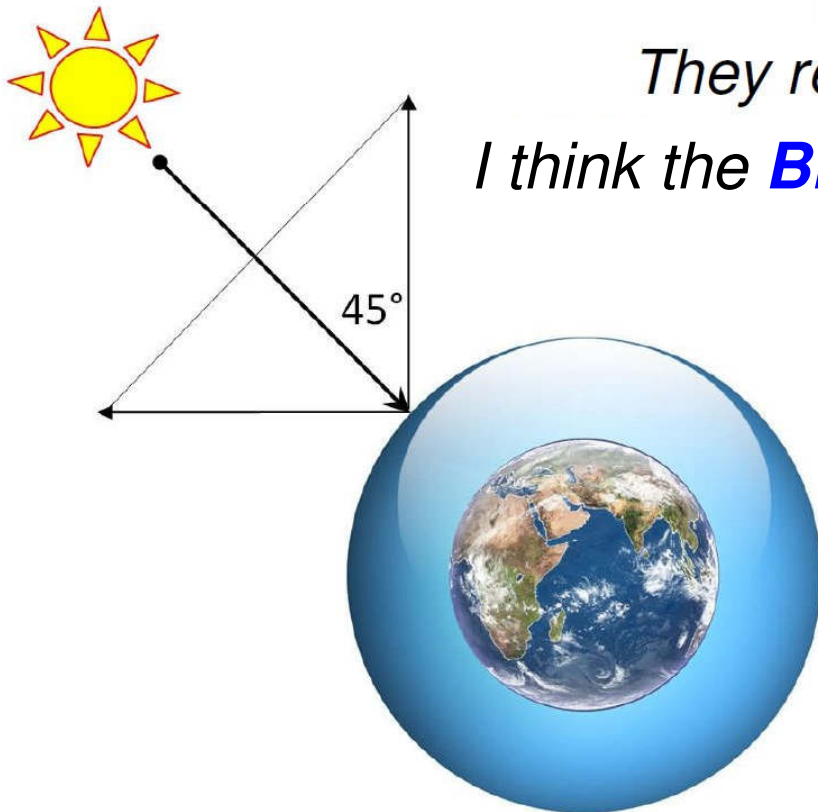
The albedo of Earth

Reviews of Geophysics

Graeme L. Stephens[1,2,3], Denis O'Brien[4], Peter J. Webster[5], Peter Pilewski[6,7], Seiji Kato[8], and Jui-lin Li[1]

"surprising" hemispheric symmetry and
"remarkable" interannual stability
of the system albedo.
Why?
*They refer to **Gaia**.*

*I think the **Blue Marble** (Glass Shell) is better:*

45°

$$\alpha_0 = 1 - \sin 45°$$
$$= 1 - \sqrt{2/2}$$
$$= 0.292893$$

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CERES - EBAF Data
Time Range: January to December - CLIMATE YEAR
Time Resolution: CLIM
Valid Range: 0 - 800
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Incoming Solar Flux (W m-2)		TOA Shortwave Flux All-Sky (W m-2)	Albedo
CLIM 1	350.69	106.26	0.30300265
CLIM 2	348.15	102.27	0.29375269
CLIM 3	343.98	99.31	0.28870865
CLIM 4	337.54	97.44	0.2886769
CLIM 5	332.3	97.45	0.2932591
CLIM 6	329.24	96.39	0.29276516
CLIM 7	328.89	93.93	0.28559701
CLIM 8	331.43	92.62	0.27945569
CLIM 9	336.78	94.79	0.28145971
CLIM 10	342.04	100.24	0.29306514
CLIM 11	347.05	106.18	0.30595015
CLIM 12	350.34	108.29	0.30909973
AVERAGE	339.8692	99.5975	0.29289938

Integer table of fluxes, all-sky
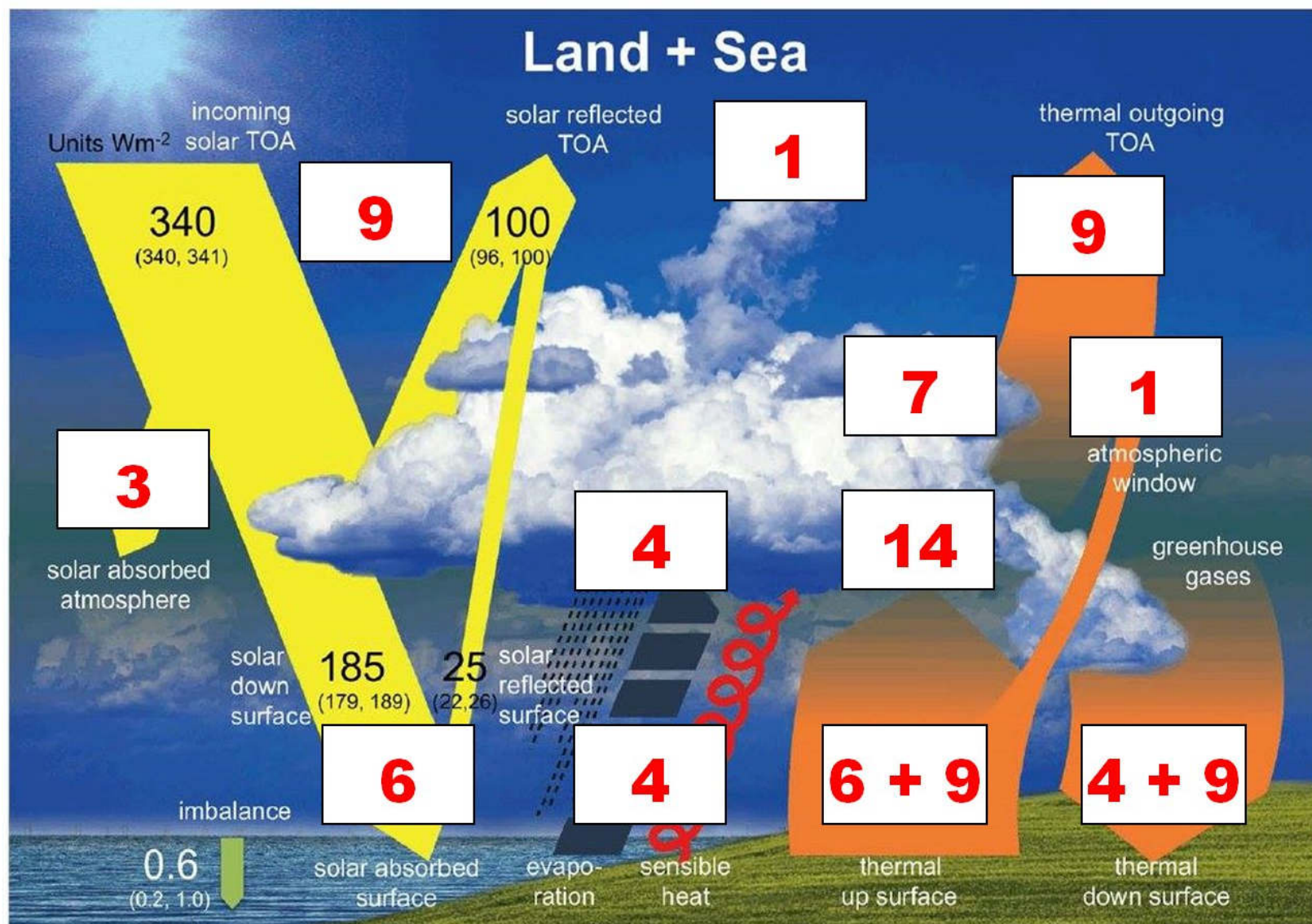
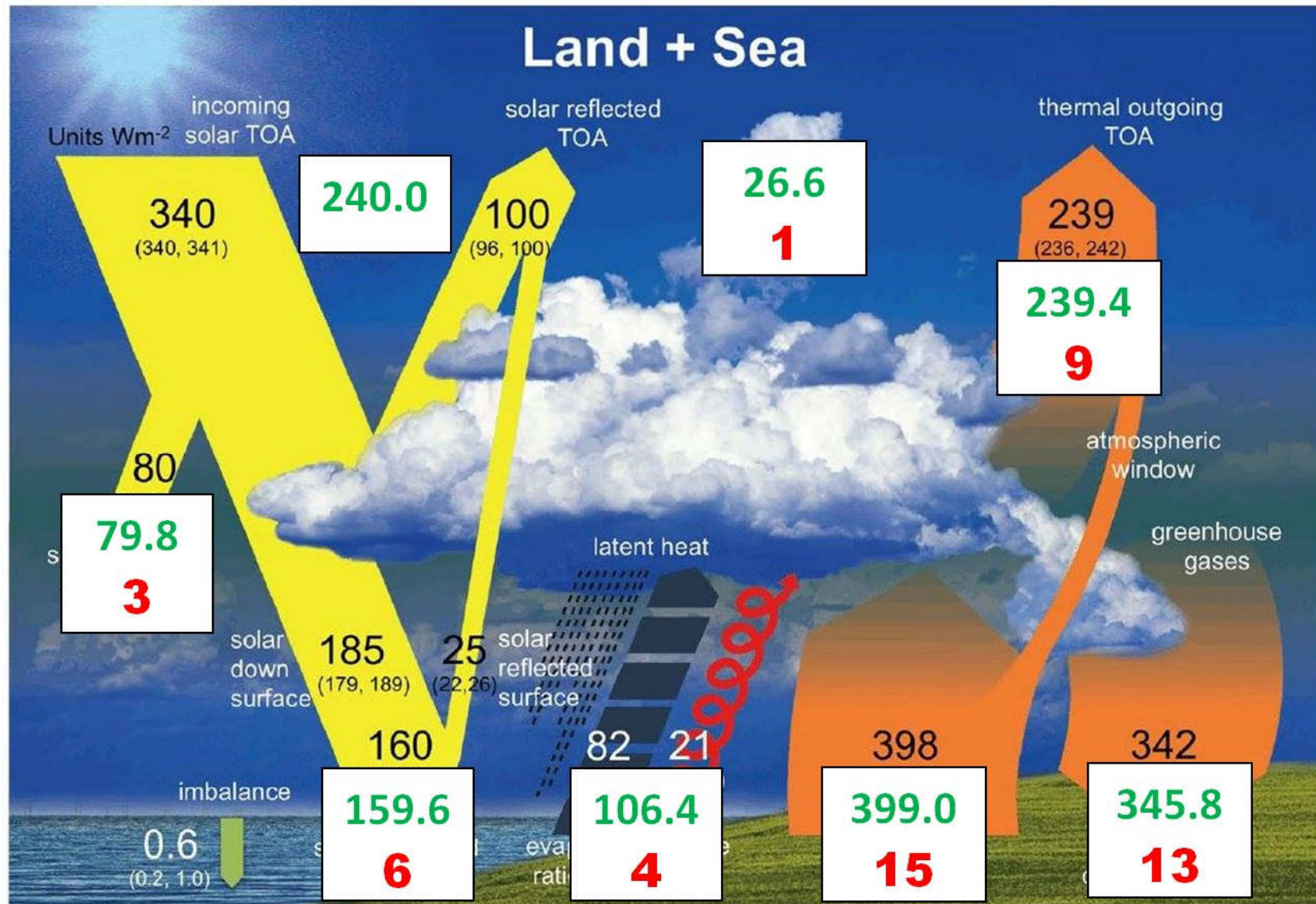|			
LongWave Cloud Radiative Effect	LWCRE	1	26.67
Sensible Heating, all-sky	SH(all)	1	26.67
Surface Transmitted Irradiance, all-sky	STI(all)	1	26.67
Net Surface Longwave radiation, all-sky	NSL(all)	2	53.3
Evaporation (Latent Heating), all-sky	LH(all)	3	80.0
Solar Absorbed by Atmosphere, all-sky	SAA(all)	3	80.0
Turbulent heat flux, all-sky	(SH + LH)(all)	4	106.7
Turbulent heat flux, clear-sky	(SH + LH)(clear)	5	133.35
Greenhouse effect, clear-sky	G(clear)	5	133.35
Greenhouse effect, all-sky	G(all)	6	159.6
Solar Absorbed by Surface, all-sky	SAS(all)	6	160.0
LongWave Cooling	LWQ	–7	–186.7
Cooling-To-Space, atmosphere	CTS(atm)	7	186.7
Cooling-To-Space, all-sky	CTS(all)	8	213.36
Solar Absorbed by Surface, clear-sky	SAS(clear)	8	213.36
Outgoing Longwave Radiation, all-sky	OLR(all)	9	240.0
Outgoing Longwave Radiation, clear-sky	OLR(clear)	10	266.7
Downward Longwave Radiation, clear-sky	DLR(clear)	12	320.0
Downward Longwave Radiation, all-sky	DLR(all)	13	346.7
Longwave Atmospheric Absorption, all-sky	LAA(all)	14	373.4
Upward LongWave emission by the surface	ULW	15	400.0
Surface energy budget, all-sky	E(SFC, all)	19	506.7
Surface energy budget, clear-sky	E(SFC, clear)	20	533.4
Atmospheric energy budget, all-sky	E(ATM, all)	21	560.1

Integer table of fluxes, clear-sky

Surface Transmitted Irradiance, clear-sky	STI(clear)	2.5	1	66.675
Turbulent heat flux, clear-sky	(SH+LH)(clear)	5	2	133.35
Greenhouse effect, clear-sky	G(clear)	5	2	133.35
Cooling-To-Space, clear-sky	CTS(clear)	7.5	3	200.0
Outgoing Longwave Radiation, clear-sky	OLR(clear)	10	4	266.7
Longwave Absorbed Atmosphere, clear-sky	LAA(clear)	12.5	5	333.4
Upward Longwave emission by the surface	ULW	15	6	400.0
Surface energy budget, clear-sky	E(SFC, clear)	20	8	533.4

Climate sudoku

Land + Sea

incoming solar TOA
Units Wm⁻²

9

1

solar reflected TOA

thermal outgoing TOA

9

340
(340, 341)

100
(96, 100)

7

1

atmospheric window

3

solar absorbed atmosphere

4

14

greenhouse gases

solar down surface
185
(179, 189)

25
(22,26)

solar reflected surface

6

4

6 + 9

4 + 9

imbalance
0.6
(0.2, 1.0)

solar absorbed surface

evapo-ration

sensible heat

thermal up surface

thermal down surface
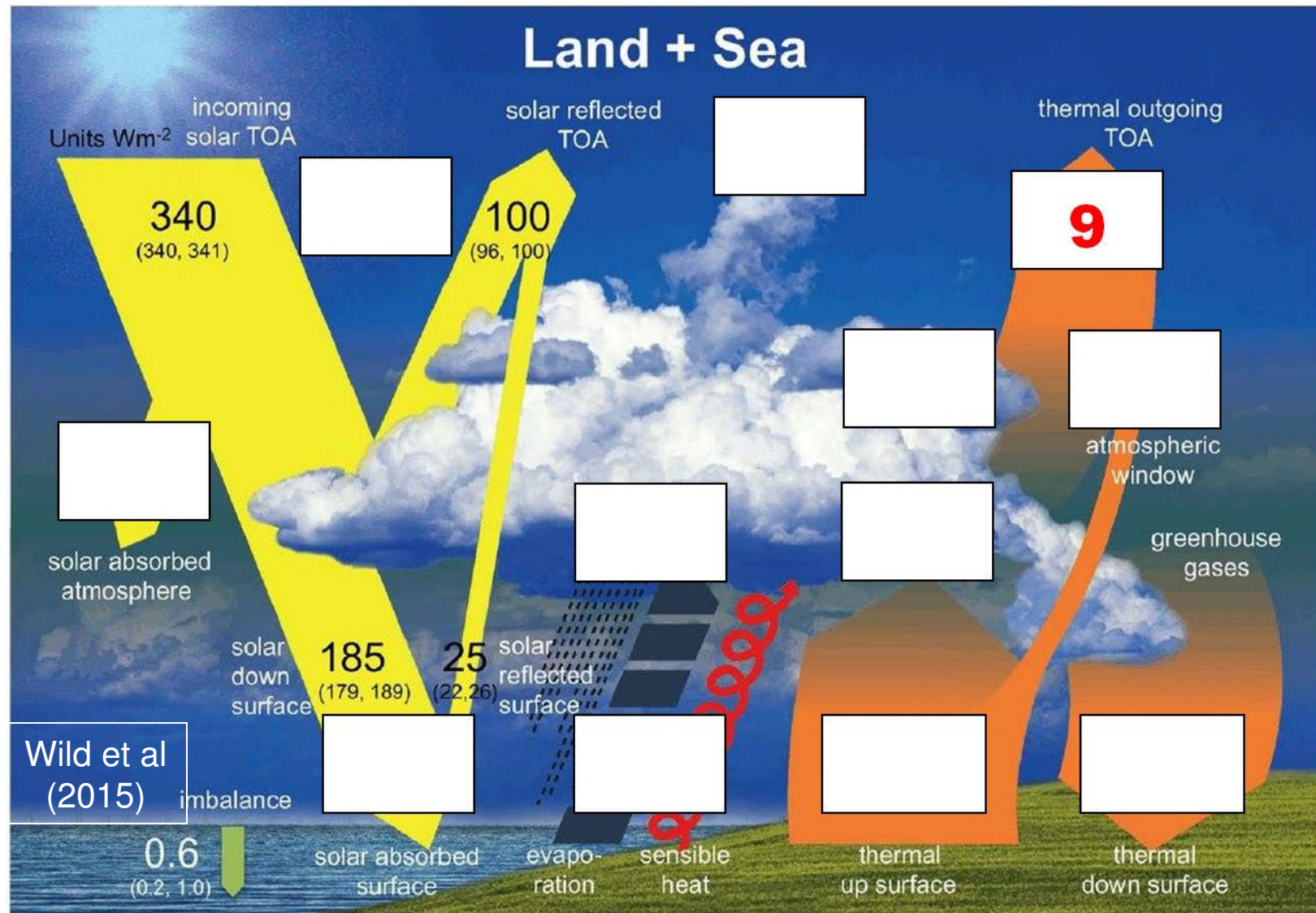
1 = 26.6 W/m², Δmax(Wild-EdMZ) = -3.8 W/m² (DLR)

Summary

- There are robust patterns in the annual global means.

- EdMZ is an idealized data set representing the pattern, belonging to a time-independent geometry.

- The integer ratios follow from the closed-shell geometry.

- The corresponding physical state has some reasonable theoretical basis.

- The largest bias between Ed4.0 and EdMZ is -6.1 Wm^{-2} (2%) in DLR(clear) and 3.6 Wm^{-2} (3.2%) in SFC SW(all).

- Size and time-scale of fluctuations around — or systematic deviations from — the pattern positions are not yet known.

The Blue Quantum Marble

2G(clear) = OLR(clear)

2OLR(clear) = E(SFC, clear)

G(clear) = SFC Net (clear)

g_0(clear) = 1/3

$\alpha_0 = 1 - \sin 45°$
$= 1 - \sqrt{2}/2$

F = $F_0 + \Delta$

$F_0 = N \times LWCRE$

g_0(all) = 2/5

$\beta_0 = 3/5$

E(SFC, all) = 2OLR(all) + LWCRE

3G(all) = 2OLR(all)

G(all) = SAS(all)
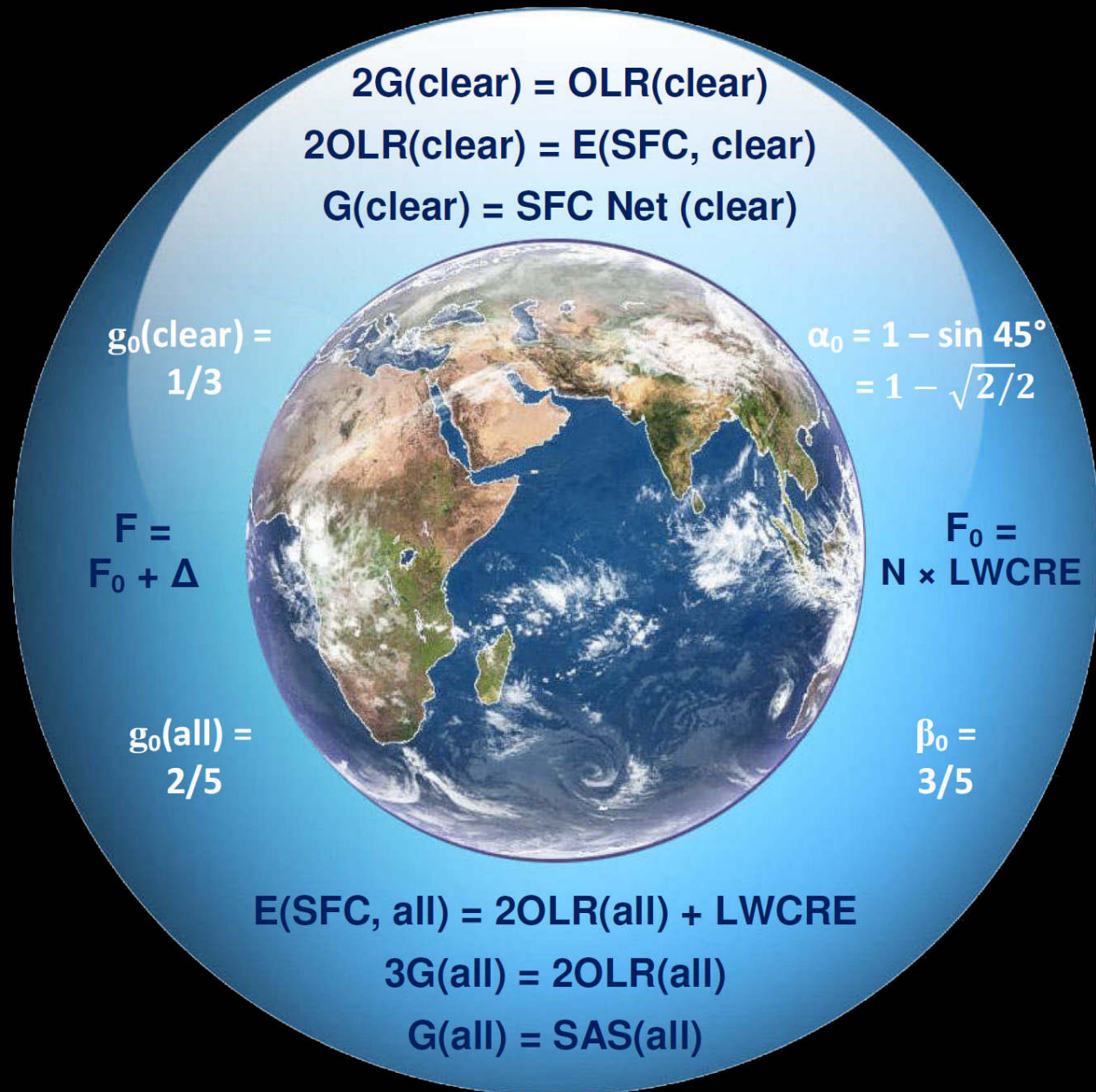
Clear-sky

$$\alpha_0 = 1 - \sin 45° = 1 - \sqrt{2}/2$$

All-sky

E(SFC) = 2OLR

E(SFC) = 2OLR + LWCRE

g = 5/15

g = 6/15

CERES

F = N × UNIT
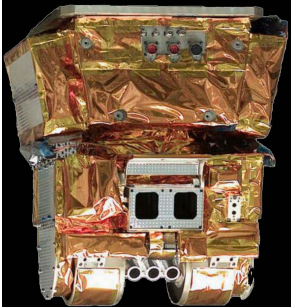
Thank you CERES Science and Data Teams!

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