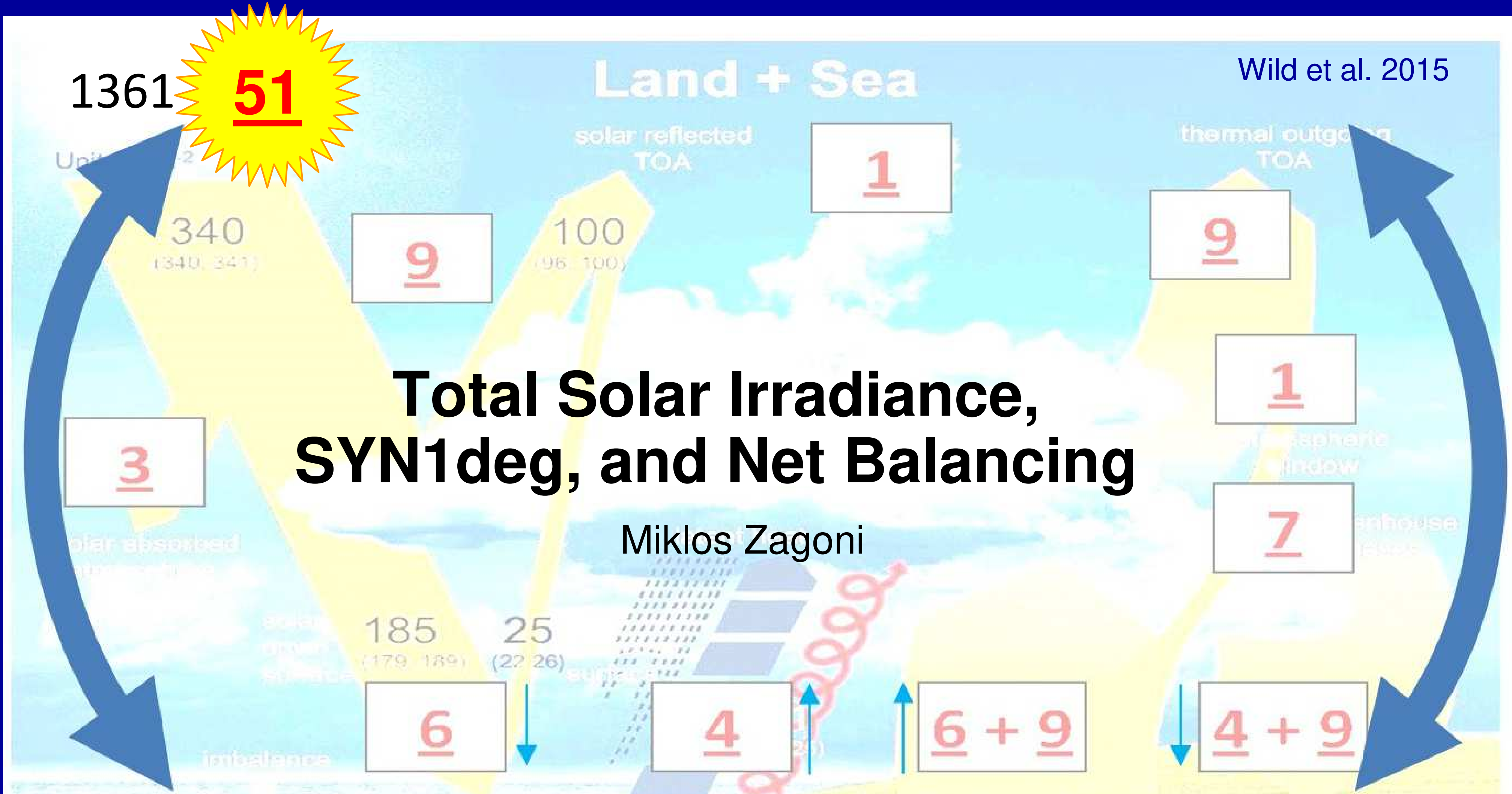
Patterns in the CERES Global Mean Data, Part 3.



Total Solar Irradiance, SYN1deg, and Net Balancing

Miklos Zagoni

31st CERES Science Team Meeting, May 9, 2019, Hampton, VA

"Instead of the traditional paradigm of properties define processes, study how processes define property" — *Graeme Stephens*

DATA: CERES SYN1deg Ed4A TOA

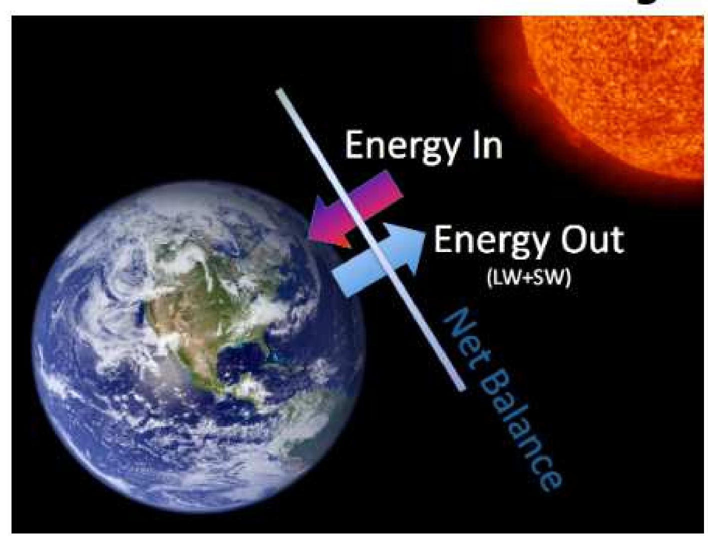
All-sky, Oct 2000 – Sep 2018 (216 months)

- TSI = 1360.9 ± 0.5
- TOA SW in = **340.0** **EBAF Ed4.0**
- TOA SW up = **97.1** **+2.0** **99.1**
- TOA LW = **238.6** **+1.5** **240.1**
- Net = **4.3**

Constraint I.

E in = E out

CERES Earth's Radiation Budget



Loeb et al. (2018) J Clim, Table 5

	EBAF Ed2.8		EBAF Ed4.0	
	Unadjusted	With constraint	Unadjusted	With constraint
Incoming Solar	339.8	339.8	340.0	340.0
All-sky LW	238.7	239.6	238.6	240.1
All-sky SW	97.9	99.6	97.1	99.1
All-sky net	3.2	0.63	4.3	0.71
Clear-sky LW	264.5	265.4	266.3	268.1
Clear-sky SW	51.5	52.5	52.3	53.3
Clear-sky net	23.8	21.9	21.4	18.6
LW CRE	25.8	25.8	27.7	27.9
SW CRE	−46.4	−47.1	−44.8	−45.8
Net CRE	−20.6	−21.3	−17.1	−17.9

The net TOA flux error due to absolute calibration uncertainty is thus $(2^2 + 3.7^2)^{½} = 4.2$ W m^{-2}.

L(2009)

A NEW Constraint in CERES SYN1deg Ed4A SFC Clear-sky Oct 2000 – Sep 2018

	SFC SW down	=	**242.65**
–	SFC SW up	=	**– 28.40**
=	SFC SW net	=	**214.25**
	SFC LW down	=	**317.77**
–	SFC LW up	=	**– 397.23**
=	SFC LW net	=	**– 79.46**
	SFC SW+LW net	**=**	**134.79**
	TOA LW	=	**268.15**
	TOA LW / 2	**=**	**134.08**
	Diff	**=**	**0.71**

Constraint II.

SFC SW+LW net

= TOA LW / 2

What Does Constraint II. Mean?

As an illustration, consider the case of radiative equilibrium with black bodies emitting $B^*(0)$ or $B^*(\tau_1)$ at the two boundaries. The third terms on the right-hand side of (2.144) and (2.145) are now zero and

$$F/2\pi = B(0) - B^*(0) = B^*(\tau_1) - B(\tau_1). \qquad (2.146)$$

Equation (2.146) requires a discontinuity in the Planck function, implying a discontinuity of temperature, at the boundary.

The class of approximation of which (2.140) is representative is extensive and a large number of different names and terms are used to describe members of the class: the *Schwarzschild–Schuster* approximation, the *Eddington* approximations, *Chandrasekhar's first*

Discontinuity in the Planck function at the boundary = $F/2\pi$

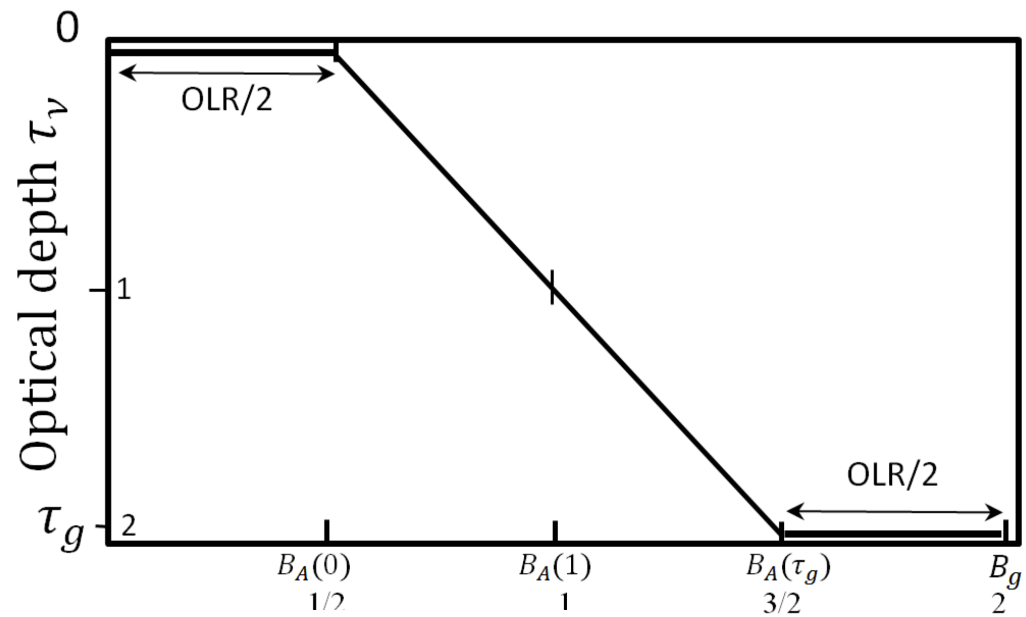
Goody and Yung (1989)

Discontinuity at the ground = OLR/2, independent of the optical thickness

Several books,
lecture notes

$$\sigma {T_A}^4 = OLR(1+\tau)/2$$

$$\sigma {T_g}^4 = OLR(2+\tau)/2$$



$$\sigma T_g(\tau_g)^4 - \sigma T_A(\tau_g)^4 = OLR/2 \text{ independent of } \tau_g$$

The temperature at the bottom of the atmosphere at τ^* is given by Equation (3.47), so that we have a discontinuity between the air temperature and that of the surface

$$T_s^4 - T(\tau^*) = T_e^4/2 \qquad (3.49)$$

Discontinuity at the ground: SFC SW+LW net = OLR/2

Constraint II.
in CERES EBAF Ed2.8
Clear-sky, CLIM YEAR

SFC SW+LW Net	**= 132.71**
TOA LW	= 265.82
(TOA LW) / 2	**= 132.91**
(TOA LW) / 2 – SFC Net	**= 0.2** ✓

Constraint II.
in CERES EBAF Ed4.0
Clear-sky, CLIM YEAR

SFC SW+LW Net	**= 130.41**
TOA LW	= 268.15
(TOA LW) / 2	**= 134.07**
(TOA LW) / 2 – SFC Net	**= 3.7**

My Net Balancing II.

Your (Constr I)

- SW gain = 1.7
- LW gain = 2.5

Parameter	TOA Flux adjustment (W/m^2)
Total SW	1.7
Total LW	2.5
Total Net	-4.2

Mine (Constr. II)	SYN		EdMZ	N
SFC SW net	= **214.25**	**– 0.81** =	213.44	**8**
SFC LW net	= **–79.46**	**– 0.58** =	– 80.04	**– 3**
SFC SW+LW net	**= 134.79**	**– 1.39 =**	**133.40**	**5**
TOA LW	= **268.15**	**– 1.35** =	266.80	**10**
TOA LW/2	**= 134.08**	**– 0.68 =**	**133.40**	**5**
Diff	**= 0.71**		**0.0**	

A THIRD constraint in CERES SYN1deg Ed4A SFC Clear-sky Oct 2000 – Sep 2018

	SFC SW down	=	**242.65**
–	SFC SW up	=	**– 28.40**
=	SFC SW net	=	**214.25**
+	SFC LW down	=	**317.77**
=	**SFC SW+LW abs**	**=**	**532.02**
	TOA LW	=	**268.15**
	2 × (TOA LW)	**=**	**536.30**
	Diff	**=**	**– 4.28**

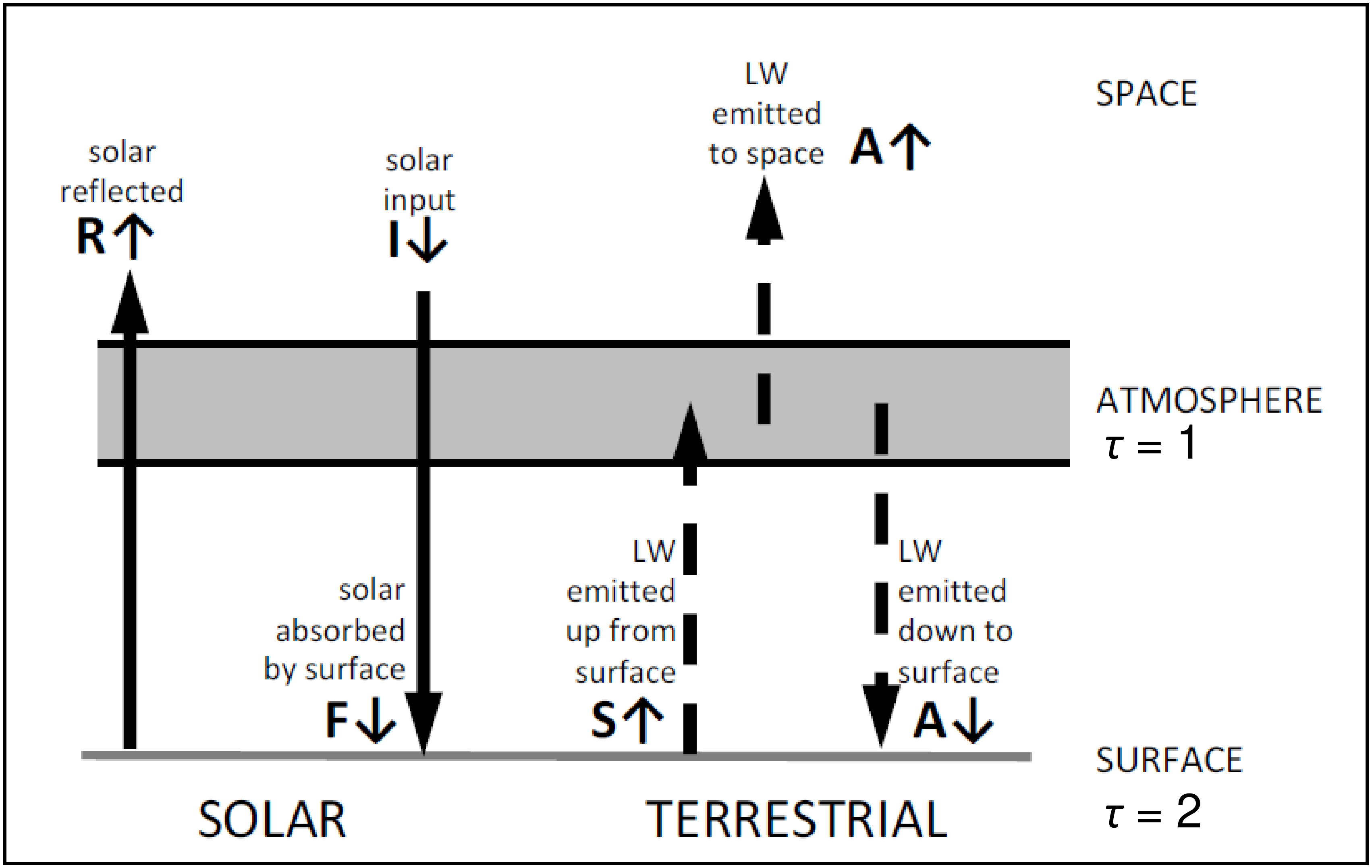
Constraint III.

SFC SW+LW abs

= 2 TOA LW

Same confidence as Constraint I.

What Does Constraint III. Mean?



S = 2A = 2F

Modified from Marshall-Plumb (2008)

Liou (1980)

Fig. 8.20, we may write down the energy balance equations at the top of the atmosphere and the surface, respectively, in the forms

$$Q(1-\bar{r}) - \bar{\varepsilon}\sigma T_a^4 - (1-\bar{\varepsilon})\sigma T^4 = 0, \tag{8.31}$$

$$Q(1-\bar{r}-\bar{A}) + \bar{\varepsilon}\sigma T_a^4 - \sigma T^4 = 0, \tag{8.32}$$

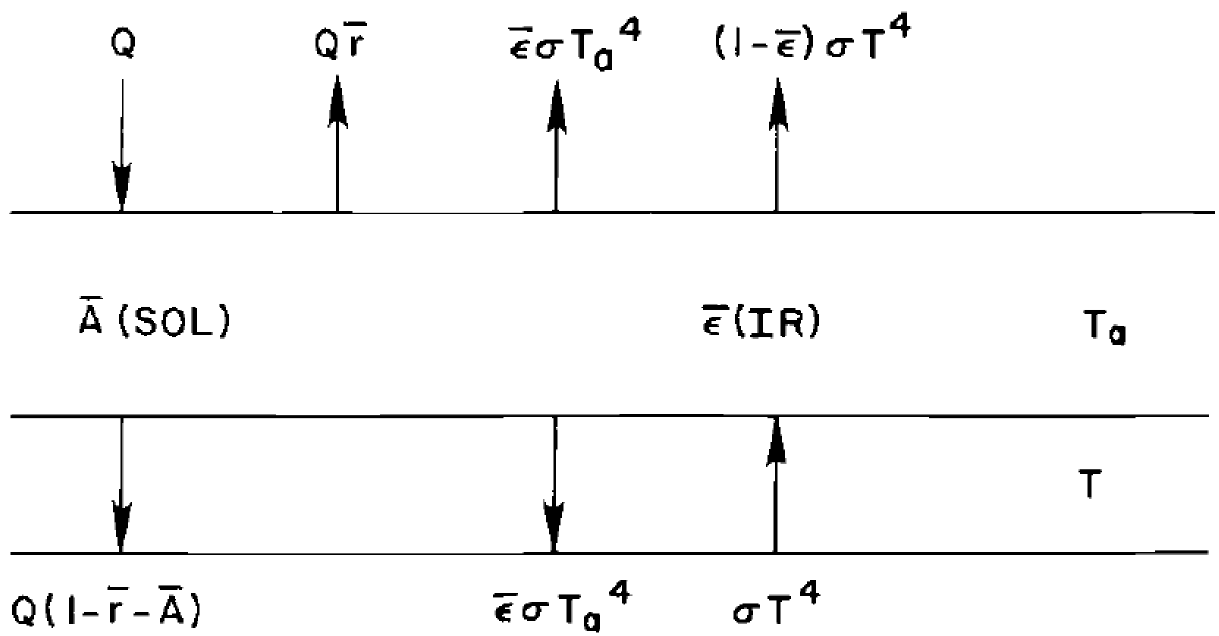


Fig. 8.20 Two-layer global radiative budget model.

Trivial solution to the radiative transfer problem

with $\bar{A} = 0$ and $\bar{\varepsilon} = 1$, $\sigma T^4 = 2\sigma T_a{}^4$

What Do Constraints II & III Mean?

Constraint II is a theoretical requirement
Constraint III is the simplest geometry

Discontinuities at the boundaries:

$$\pi \Delta B_0 = \pi \Delta B_g = F_S/2 = OLR/2,$$

independent of τ .

$$\pi B_0 = \sigma {T_0}^4 = F_S(1+\tau)/2$$

$$\pi B_g = \sigma {T_g}^4 = F_S(2+\tau)/2$$

With $\tau_g = 2, \;\; \pi B_g = 2F_S = 2OLR.$

They, together, describe a unique, specific state

Why are they important?

- **Mars: E(SFC) << 2OLR**

  E(SFC) = (SW+LW) abs = 123 Wm^{-2}
  2OLR = 2 × 110; WIN = 97 Wm^{-2};

  E(SFC) = 2OLR – WIN the value of WIN is missing

  No clouds, leaky greenhouse: WIN is lost without compensation

- **Venus: E(SFC) >> 2OLR**
  E(SFC) = 2OLR + k × SFC LWCRE
  Multiple-closed cloud layers, WIN = 0

- **Earth: E(SFC, clear) = 2 OLR(clear) = 2 × 266.8 Wm^{-2}**

  E(SFC, clear) = 2 ASR(clear) – WIN(clear) + LWCRE

  E(SFC, clear) = 2 × 286.81 – 66.70 + 26.68 EXACT !

- Earth: E(SFC, all) = 2OLR(all) + LWCRE

  Leaky greenhouse + partial cloud cover:
  Atmospheric window closed by the blanketing effect of clouds

WIN(clear) = 66 W m^{-2}

Outgoing Longwave Radiation due to Directly Transmitted Surface Emission

S. M. S. COSTA

Center for Weather Forecasts and Climate Studies, National Institute for Space Research, Cachoeira Paulista, Brazil

K. P. SHINE

Department of Meteorology, University of Reading, Reading, United Kingdom

(Manuscript received 22 September 2011, in final form 22 December 2011)

ABSTRACT

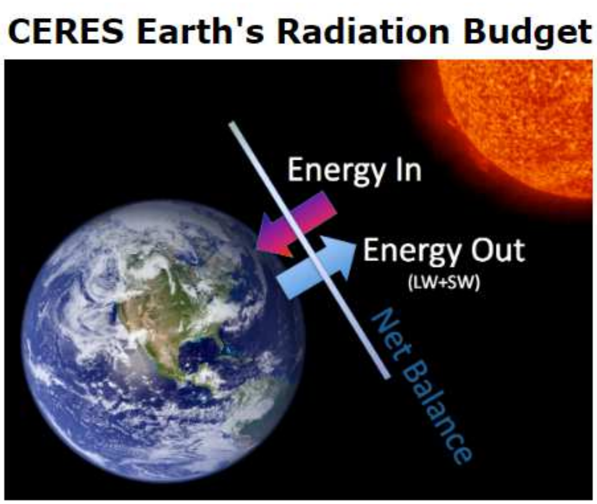
A frequently used d … t of the earth and
atmosphere indicates t … urface, through the
midinfrared atmospher … longwave radiation
(OLR) of about 235 W … r. A more detailed
calculation of this comp … sented, using a line-
by-line radiation code a … assumption is made
as to the wavelengths at … ere. The role of the
water vapor continuum … global- and annual-
mean STI is calculated … pics and subtropics.
When the continuum is … nctly different geo-
graphic distribution, wi … ts. The inclusion of
clouds reduces the STI … r due to processes
neglected here, and an … 0%) is suggested to
be much more realistic … an one-tenth of the
OLR originates directly from the surface.

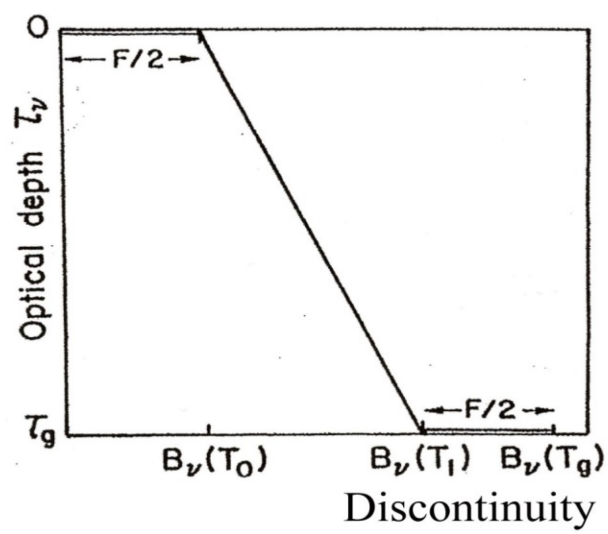
s 40 W m^{-2}; this can be compared to the to
value of 40 W m^{-2} was estimated in an a
ned here the surface transmitted irradiance
atologies of temperature, humidity, cloudi
ation from the surface can reach the top of
ated. In clear skies, if the continuum is ex
100 W m^{-2} with a broad maximum throu
the clear-sky STI is reduced to 66 W m^{-2}
um in the tropics and local peaks over subt

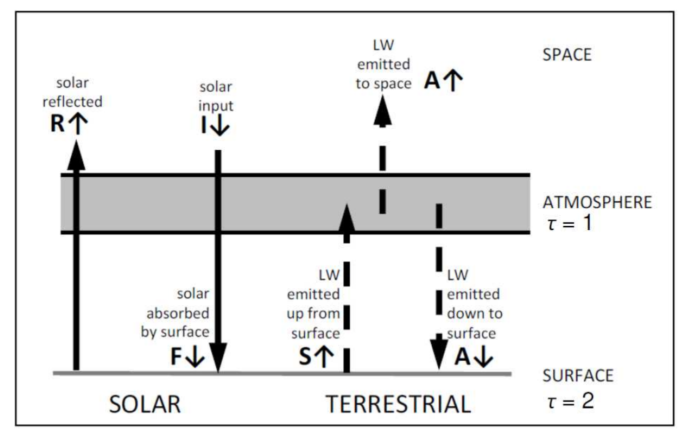
Constraints I, II and III.

The One, The Half and The Double

ASR	SFC Net	SFC Gross
= OLR	= OLR/2	= 2OLR







Universal necessity

Theoretical requirement

Simplest model

Constraint III.
in CERES EBAF Ed2.8
Clear-sky, CLIM YEAR

	SYN		Ed2.8
SFC SW net	**214.25**	+ 0.09	= 214.34
SFC LW down	**317.77**	– 1.49	= 316.28
SW+LW gross	**532.02**	**– 1.40**	**= 530.62**
TOA LW	**268.15**	– 2.55	= 265.60
2(TOA LW)	**536.30**	**– 5.10**	**= 531.20**
DIFF	**– 4.28**		**0.58** ✓

Constraint III.
in CERES EBAF Ed4.0
Clear-sky, CLIM YEAR

	Ed4.0	SYN	My	EdMZ	Integers
SFC SW net	= 213.99	214.25	– 0.81	213.44	**8**
SFC LW down	= 314.02	317.77	+ 2.39	320.16	**12**
SW+LW abs	**= 528.01**	**532.02**	**+ 1.58**	**533.60**	**20**
TOA LW	= 268.04	268.15	– 1.35	266.80	**10**
2(TOA LW)	**= 536.08**	**536.30**	**– 2.70**	**533.60**	**20**
DIFF	= **– 8.1**	**– 4.28**		**0.0**	

My Net Balancing I.

Total Solar Irradiance = **1360.68** Wm^{-2} = **51** units

1 unit = TSI / **51** = **26.68** Wm^{-2}

Incoming Solar Radiation	= **51**/4	= **340.17** Wm^{-2}
Reflected all-sky disk	= **15** units	
Absorbed all-sky disk	= **36** units	
Reflected all-sky sphere	**= 15/4 units**	**= 100.05**
Absorbed all-sky sphere	= **36/4 units**	= **240.12**
Reflected clear-sky disk	= **8** units	
Absorbed clear-sky disk	= **43** units	
Reflected clear-sky sphere	**= 8/4 units**	**= 53.36**
Absorbed clear-sky sphere	= **43/4 units**	= **286.81**

My Net Balancing I – II – III.

UNIT = 26.68 Wm^{-2}	SYN	Mine	N × UNIT	N
TSI	= 1360.9	– 0.22	= 1360.68	51
TOA SW up all	= 97.32	+ 2.73	= 100.05	15 / 4
TOA LW up all	= 238.63	+ 1.49	= 240.12	36 / 4
TOA SW up clr	= 51.38	+ 1.98	= 53.36	8 / 4
TOA LW up clr	= 268.15	– 1.35	= 266.80	40 / 4
SFC SW+LW net clr	= 134.79	– 1.39	= 133.40	5
(TOA LW)/2 clr	= 134.08	– 0.68	= 133.40	5
SFC SW net clr	= 214.25	– 0.81	= 213.44	8
SFC LW down clr	= 317.77	+ 2.39	= 320.16	12
SFC SW+LW abs clr	= 532.02	+ 1.58	= 533.60	20
2 × (TOA LW) clr	= 536.30	– 2.70	= 533.60	20
G(clear-sky)	= 129.08	+ 4.32	= 133.40	5
G(all-sky)	= 159.36	+ 0.72	= 160.08	6

SYN1deg Ed4A Oct 2000-Sep 2018 (216 months)

	gtoa_lw_clr_m	gini_sfc_sw_u	gini_sfc_sw_down_clr_mon		gini_sfc_lw_d	gini_sfc_lw_u	gtoa_lw_all_m	gini_sfc_lw_u	gini_sfc_lw_dc
1	268.6685	28.729	245.956	217.227	314.643	395.639	237.188	396.402	346.671
2	266.3501	32.9542	253.268	220.314	308.936	390.02	235.423	390.781	340.802
3	265.2815	32.9676	255.533	222.565	305.854	386.45	235.24	387.196	336.901
4	264.6424	30.878	254.399	223.521	306.085	386.151	235.258	386.877	336.332
5	265.2581	28.9934	250.152	221.158	308.618	387.512	235.121	388.251	338.59
6	266.3788	29.23	246.101	216.871	312.659	392.024	235.357	392.763	341.933
212	268.8642	30.0937	236.001	205.908	321.927	402.821	239.318	403.546	350.415
213	270.9259	27.2861	231.366	204.08	326.345	406.171	241.744	406.857	354.49
214	272.1338	24.4367	228.875	204.438	329.65	407.483	242.749	408.152	357.083
215	271.3511	23.0617	231.194	208.133	328.536	406.628	242.32	407.307	356.497
216	269.9651	24.2759	237.874	213.598	323.429	403.484	241.155	404.171	352.004
	268.15	**28.40**	**242.6**	**214.25**	**317.77**	**397.23**	**238.63**	**397.96**	**347.27**
	134.08			**134.79**		**0.71**			
	536.30			**532.02**		**– 4.28**			

SYN1deg