

Review of NOAA Working Group Report on Maintaining the Continuation of Long-term Satellite Total Solar Irradiance Observation

Graeme Stephens, Committee Chair

Plus some surprising properties of the sunlight
from Earth*

Stephens, Webster, OBrien, Pilewskie, Kato and Li,
2014; The Albedo of Earth - *Rev Geophys*.

Charge to the Committee

Measurement of total solar irradiance is an important long-term climate record. An ad hoc committee appointed by the National Research Council will evaluate NOAA's plan for mitigating the loss of total solar irradiance measurements from space, given the likelihood of losing this capacity from instruments currently on the SORCE satellite in coming years and the short-term/experimental nature of the currently identified method of filling the data gap (interim observations from TCTE). The committee will evaluate NOAA's plan for mitigating the gap in total solar irradiance data (including consideration of two commissioned papers upon which NOAA is basing its plan). The committee's evaluation will include consideration of:

- Whether the plan appropriately reflects the scientific content of the commissioned papers,
- Whether the potential alternate method in the plan maintains the integrity of the data record,
- Whether the plan adequately summarizes the strengths and weaknesses of the proposed approach, and
- Whether the background documents and plan together fully explore the implications of loss of or changes in measurement on the understanding of Earth's climate system and processes.

Committee Membership

GRAEME L. STEPHENS, *Chair*
Jet Propulsion Laboratory

JOANNA D. HAIGH
Imperial College London

JACK HARVEY
National Solar Observatory

CHARLES ICHOKU
NASA Goddard Space Flight Center

BRUCE WIELICKI
NASA Langley Research Center

KUO-NAN LIOU
University of California, Los Angeles

WILLIAM SMITH
Hampton University

JOSHEPH RICE
National Institute of Standards and Technology

Findings

Question 1: Does the plan appropriately reflect the scientific content of the commissioned papers?

Finding 1: The Committee found that the plan faithfully followed the Kopp and Lean studies. The plan also displayed an admirable degree of nimbleness in reacting to a pressing need to fill an impending CDR gap. The solution presented was a creative, rapid, and low-cost response that exploited the availability of an existing engineering instrument model, and heritage in engineering, mission architecture, and data analysis. Studies A and B themselves also provide a useful analysis that furthers our understanding of the performance of existing space-borne TSI measurements.

Findings

Question 2: Does the potential alternate method in the plan maintain the integrity of the data record?

Finding 2.a: Study B clearly argues that the CDR requirements can only be met when data overlap occurs at both ends of the gap. Because no reliability estimates of mission components or information about mission funding or Air Force support were provided, it was not possible to assess the real likelihood of the gap being filled. The Committee concluded that the plan is unable to ensure the integrity of the data record because as presented it is a 1.5 year plan to fill a 3+ year gap.

Findings

Question 2: Does the potential alternate method in the plan maintain the integrity of the data record?

Finding 2.b: The launch of TCTE is currently scheduled for October 30, 2013, which will likely ensure overlap with SORCE. Although not presented to the Committee, it appears the probability is high of SORCE operating beyond the launch of TCTE, thus providing critical overlap at the front end of the gap.

Finding 2.c: The likelihood of achieving 4 years of data on orbit and thus overlap with the JPSS/TSIS (scheduled to launch in late 2016 to early 2017) is 0.56, or slightly better than 50%. If the launch slips to 2018, the probability of overlap drops to 0.48. If it slips to 2019, the probability of overlap drops further to 0.41.

Findings

Question 2: Does the potential alternate method in the plan maintain the integrity of the data record?

Finding 2.d: The NOAA Working Group report did not provide information on funding support for the TCTE mission and stated that NOAA is working with the Air Force to ensure operation of the STPSat-3/TCTE mission for as long as possible. Continued funding and cooperation from the Air Force will be necessary for continued data collection and maintaining the integrity of the data record.

Findings

Question 3: Does the plan adequately summarize the strengths and weaknesses of the proposed approach?

Finding 3: Taken together, the three documents provided a balanced discussion of strengths and weakness of the proposed method to fill the TSI gap and recognized fully the limitations of the proposed TCTE gap filler. The Committee considered material from the NOAA Working Group Report, Kopp and Lean Studies A and B, the SORCE and ACRIM-3 NASA Senior Review proposals, existing literature on TSI observations, and past changes in TSI records needed to correct instrument artifacts. Overall, the arguments in favor of TIM as the current best reference were the most compelling.

Findings

Question 4: Do the background documents and plan together fully explore the implications of loss of, or changes in, measurement on the understanding of Earth's climate system and processes?

Finding 4: The Committee's research on the source of the CDR requirements suggests they derive from empirical knowledge of solar variability and instrumental capability. **To determine the implications of these requirements on the understanding of the Earth's climate system, the Committee considered two different pathways for setting these requirements based on climate sensitivity.** Coincidentally, the outcome of the calculations agrees with the pre-defined CDR requirements. Hence, given that the plan and the background documents together made their recommendations based on these requirements, the Committee considers that these documents, to an appreciable extent, explored the implications of loss of, or changes in, TSI measurements on the understanding of Earth's climate system and processes.

Table 1. CDR Requirements for the JPSS/TIM

Parameter	CDR Requirement
Absolute Accuracy	0.01% (100ppm; 0.14Wm^{-2})
Stability (long-term precision)	0.001%/yr (10 ppm/yr; $0.014\text{Wm}^{-2}/\text{yr}$)
Noise (short-term precision)	0.001% (10 ppm; 0.014Wm^{-2})

Note: $1\text{ppm} \sim 0.0014\text{Wm}^{-2}$

Additional Thoughts

- **Use all data sources:** It is beyond this Committee's charge to prioritize other options (e.g., proxy data models versus other space instruments). However, the Committee does note that NOAA would be wise to utilize all available data resources to fill the gap.
- **Two CDRs:** There are two TSI records, the shorter, more accurate TIM-era record and the full 33+ year record. The impact of the gap on the 33+ year record was not considered but needs evaluation
- **Need for a climate observing system:** The TCTE solution is not optimal in a scientific sense given roughly 50 percent likelihood of successful overlapping observations in the best case scenario of an on-time JPSS FF-1 launch combined with an absence of any programmatic issues in NOAA and Air Force collaboration on extending the TCTE mission life from 2 to 4 years. Yet in the context of the lack of a climate observing system, the TCTE solution can be considered optimal within the constraints present. We should expect similar issues in the future with many of the approximately 50 essential climate variables.

For more information

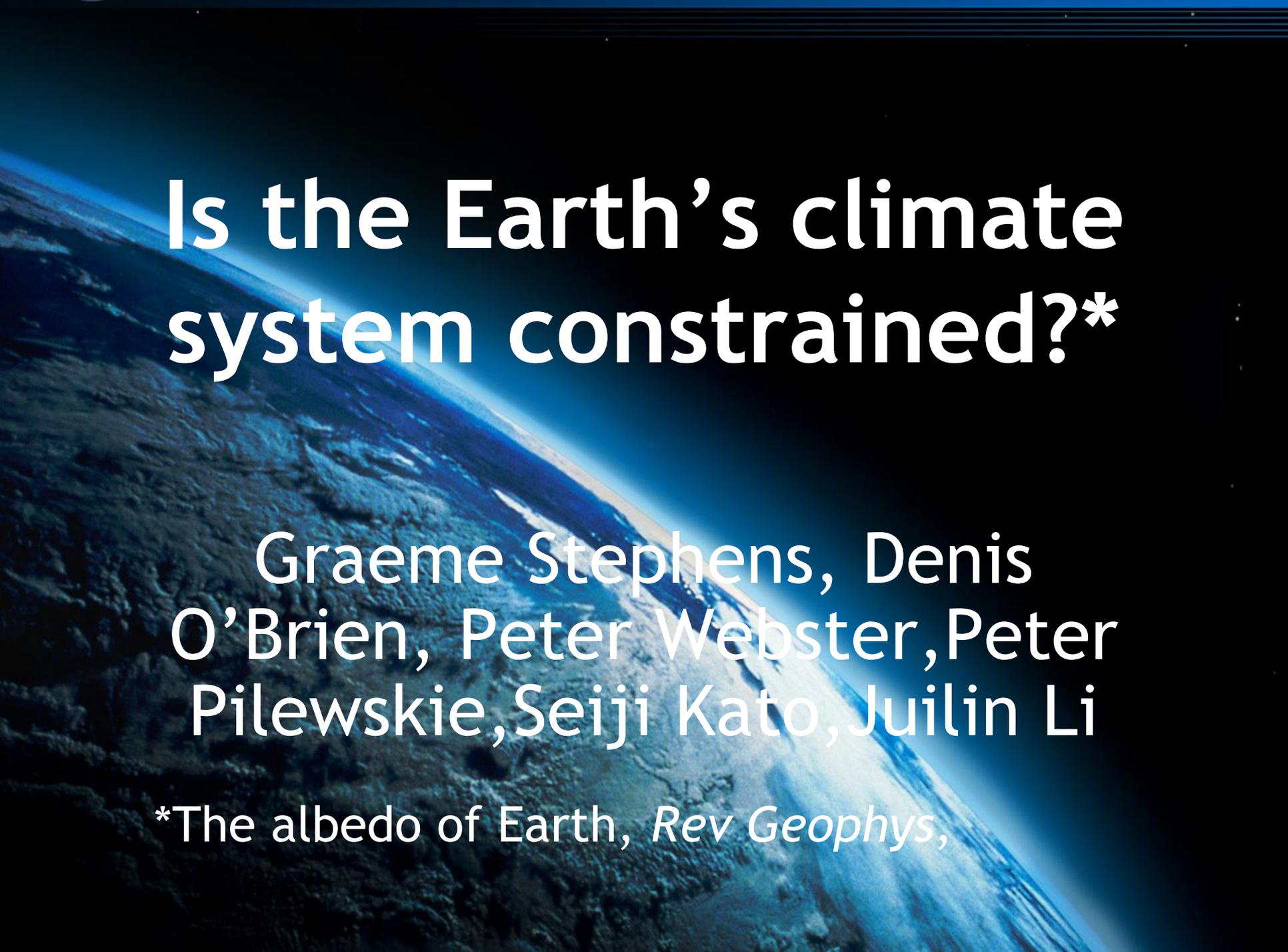
National Research Council

Maggie Walser

202.334.3614

[mwalsers@nas.edu](mailto:mwalser@nas.edu)

Report is available online at www.nap.edu.



Is the Earth's climate system constrained?*

Graeme Stephens, Denis O'Brien, Peter Webster, Peter Pilewskie, Seiji Kato, Juilin Li

*The albedo of Earth, *Rev Geophys*,

I will (partially) address three basic questions :

- Is the real Earth's Climate system constrained?
- If some overriding constraint exists, what is its significance?
- Are models similarly constrained?

Energy balance perspective

PROGRESS ARTICLE

NATURE GEOSCIENCE DOI: 10.1038/NCEO1580

Box 1 | Updated energy balance

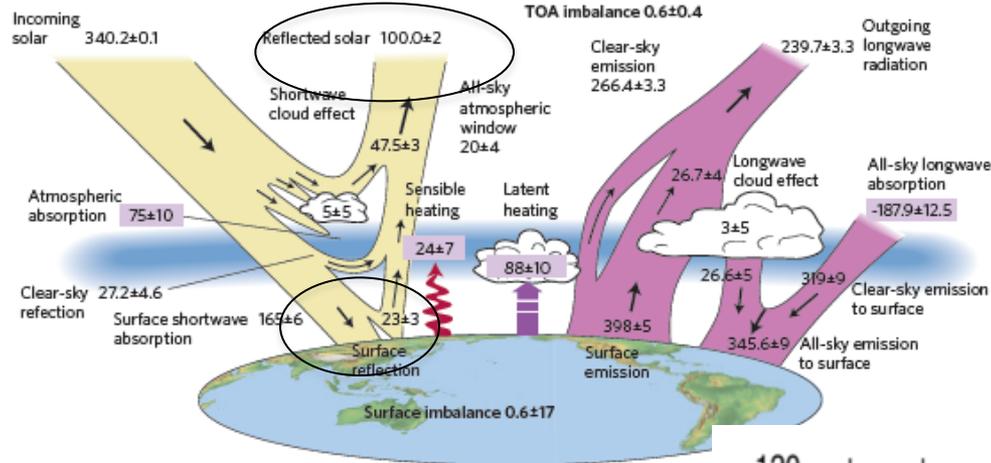
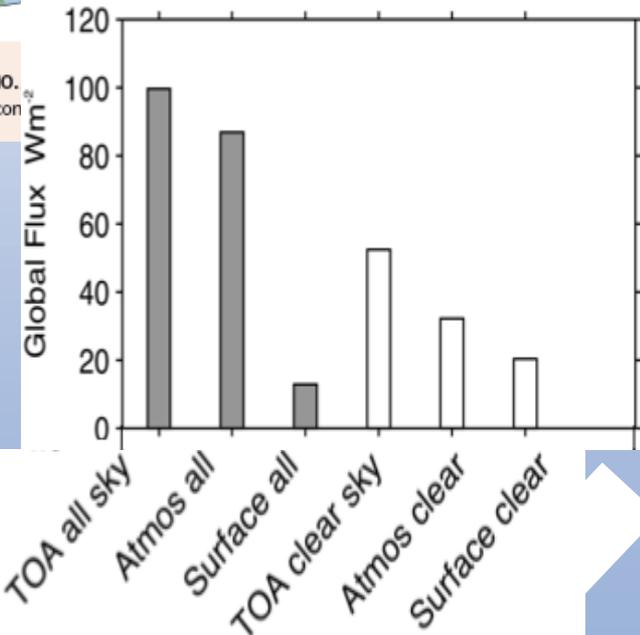
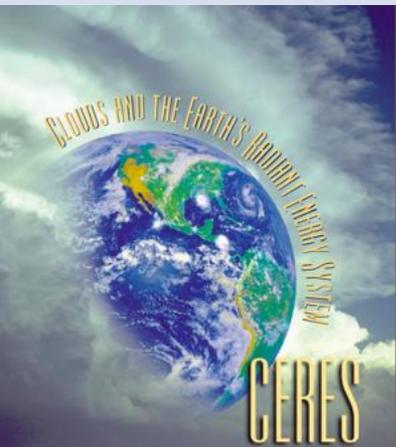


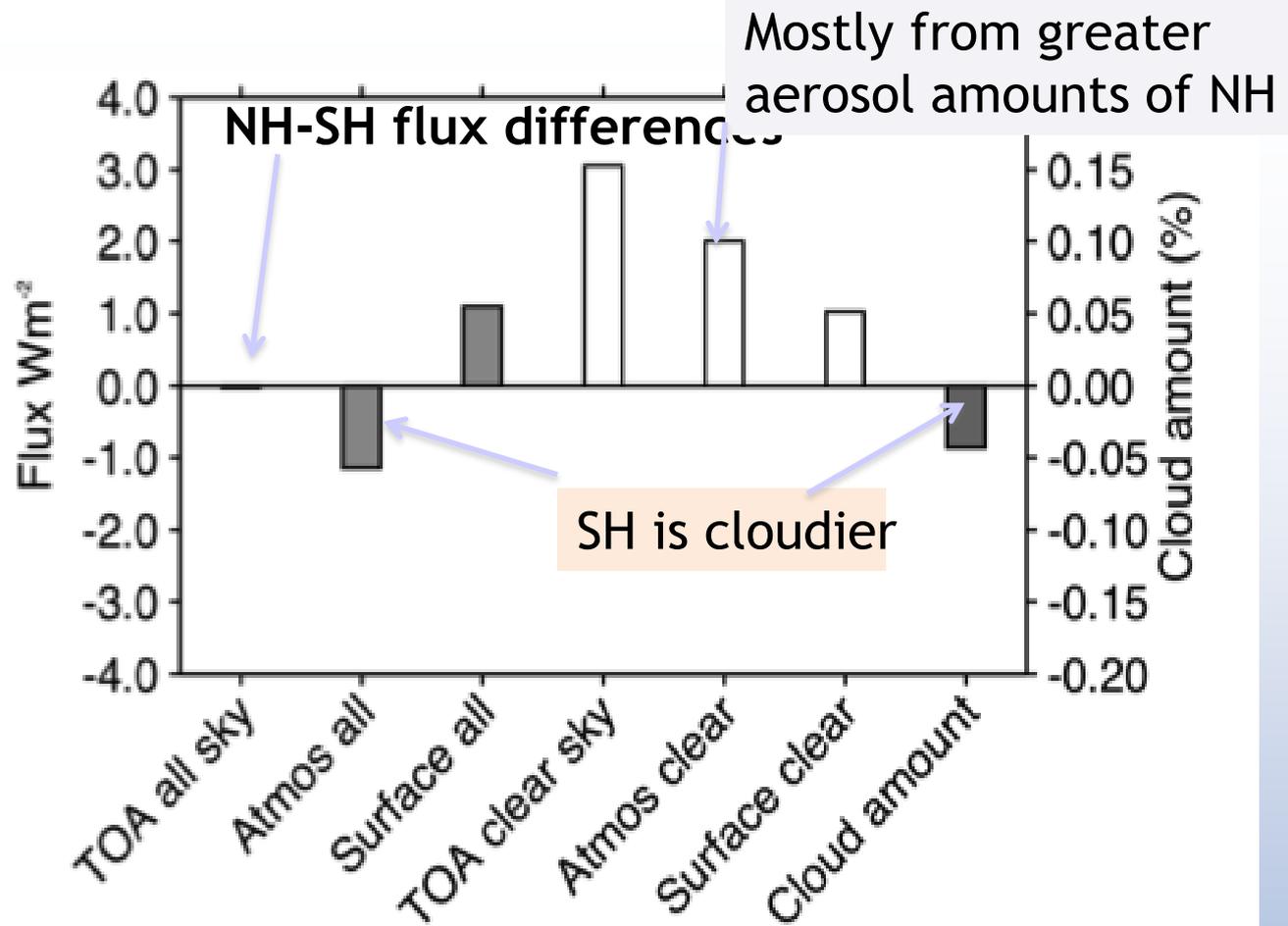
Figure B1 | The global annual mean energy budget of Earth for the approximate period 2000–2010, and infrared fluxes in pink. The four flux quantities in purple-shaded boxes represent the principal con-



Data sources considered:

- CERES EBAF2.6r Loeb et al., 2009
- CERES EBAF surface fluxes, Kato et al., 2009
- CloudSat/CALIPSO Geoprof

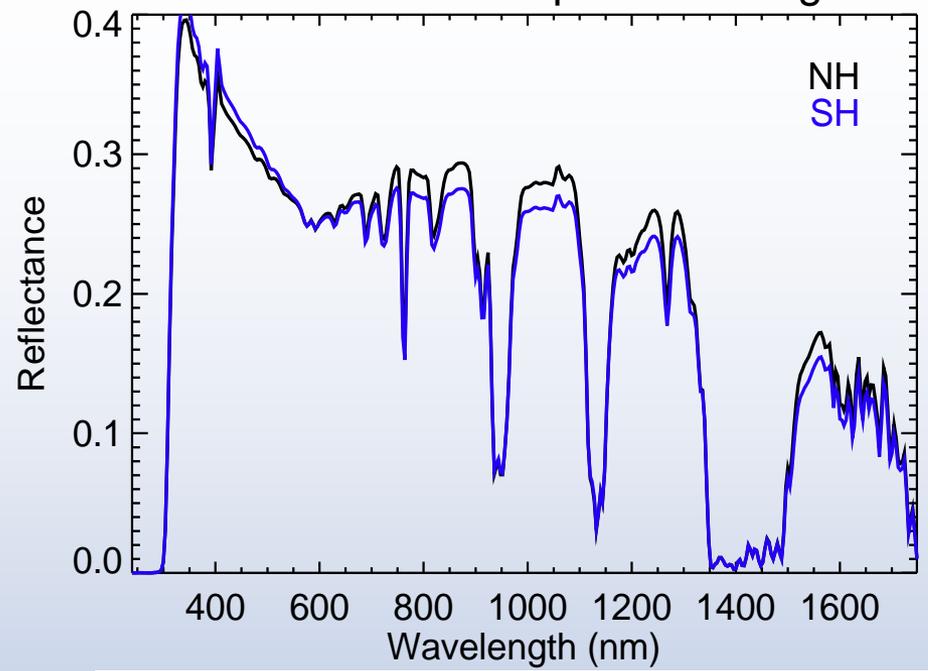




Although the hemispheres are structurally different, the reflected flux is ~ identical ($\sim 0.02Wm^{-2}$; Stephens et al., 2014; $0.1Wm^{-2}$ Voigt et al., 2012).

SCHIAMARCHY DATA

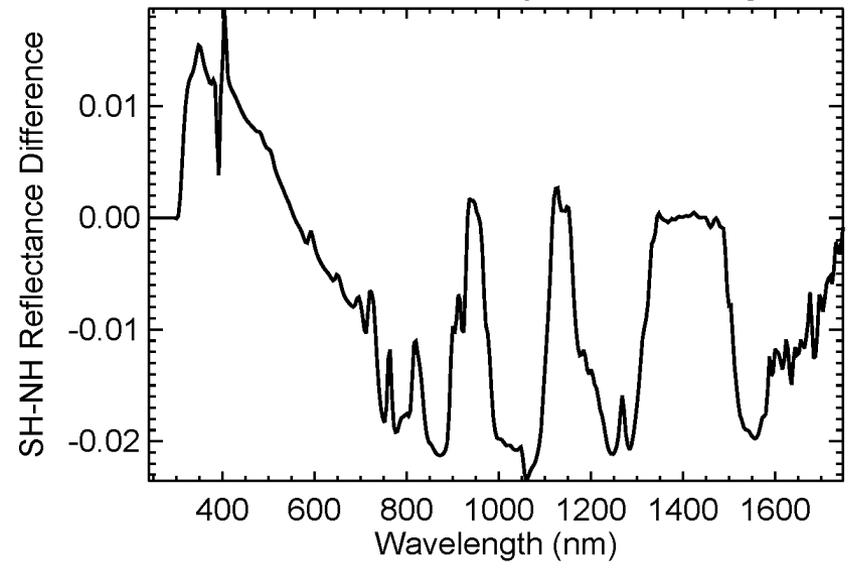
2003-2010 Hemisphere Average



Further support

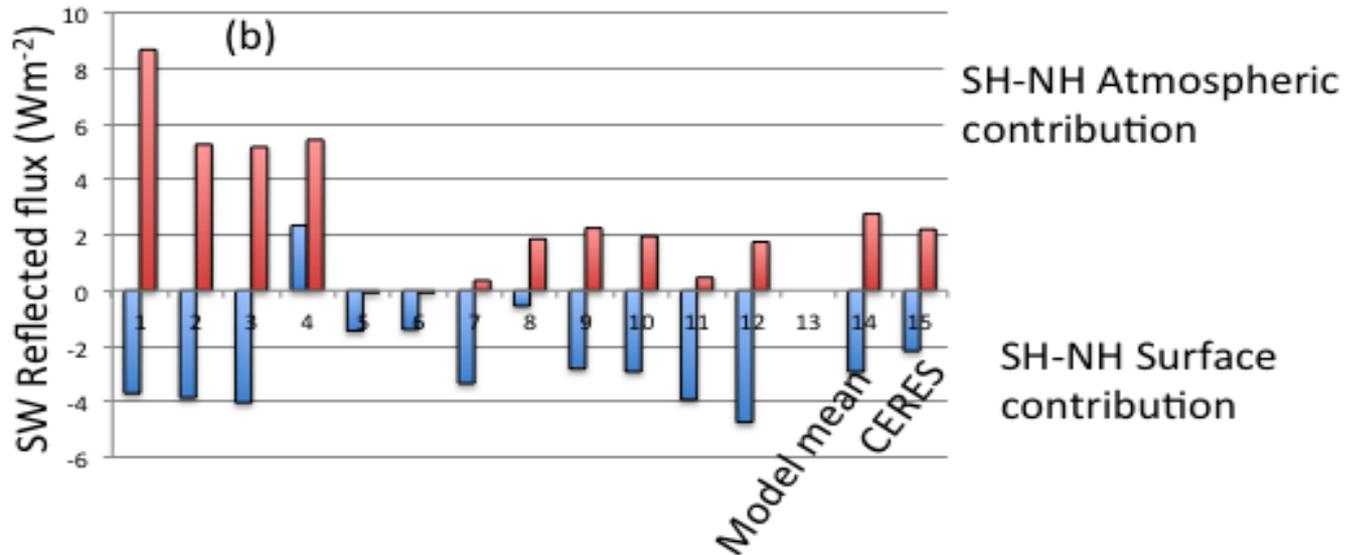
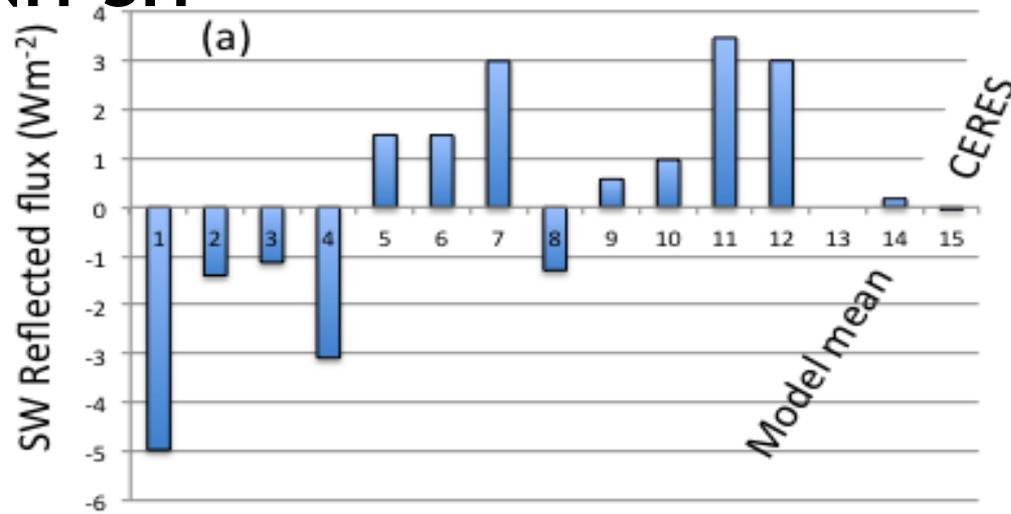
Is this accidental (Voigt et al., 2012)?

2003-2010 Hemisphere Average



CMIP5 analysis

NH-SH

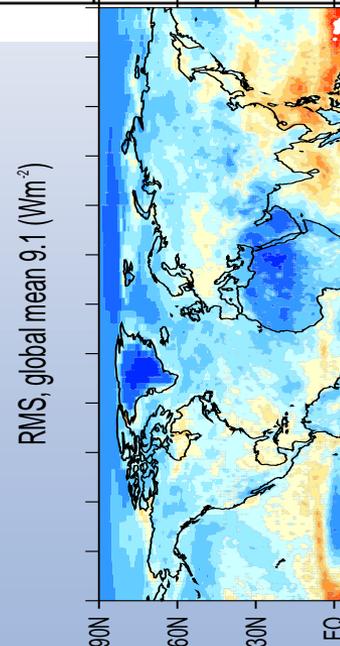


1) There is a general lack of hemispheric symmetry in models

2) The reasons for this vary - in some models the SH clouds are too bright, others these clouds aren't bright enough & yet in others the surface is too bright

Averaging Scale	Total		Atmosphere		Surface	
	Flux	σ (x)	Flux	σ (x)	Flux	σ (x)
Global	99.7	0.23	86.9	0.29	12.9	0.10

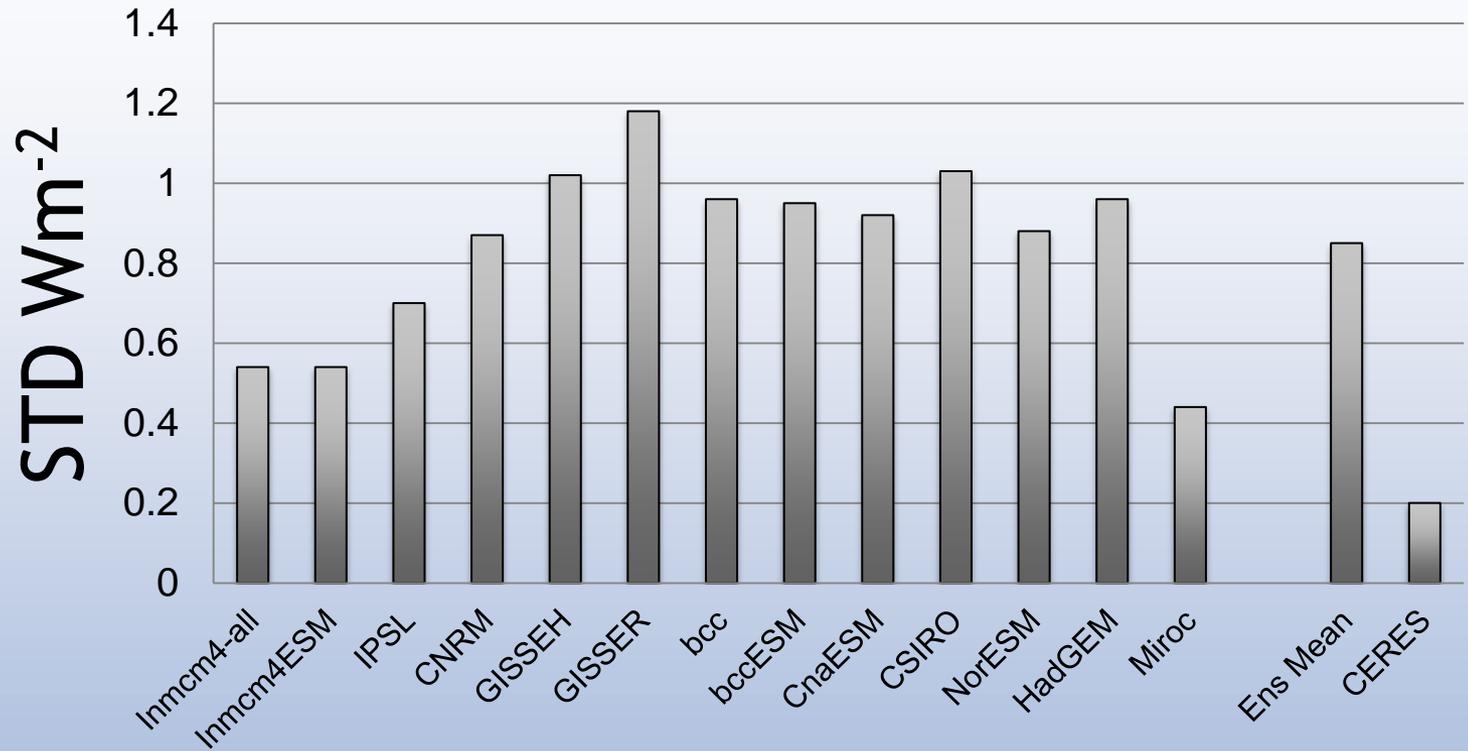
(30N-30S)						
Mid-latitude NH(30-60N)	103.8	0.52	91.5	0.53	12.3	0.15
Mid-latitude SH(30-60S)	104.1	0.56	98.9	0.65	5.26	0.10
Polar NH (60-90N)	97.0	0.87	78.7	0.87	19.1	0.47
Polar SH (60-90S)	118.8	0.68	84.4	1.26	35.5	0.97



Variability is mostly from clouds and is highly regulated

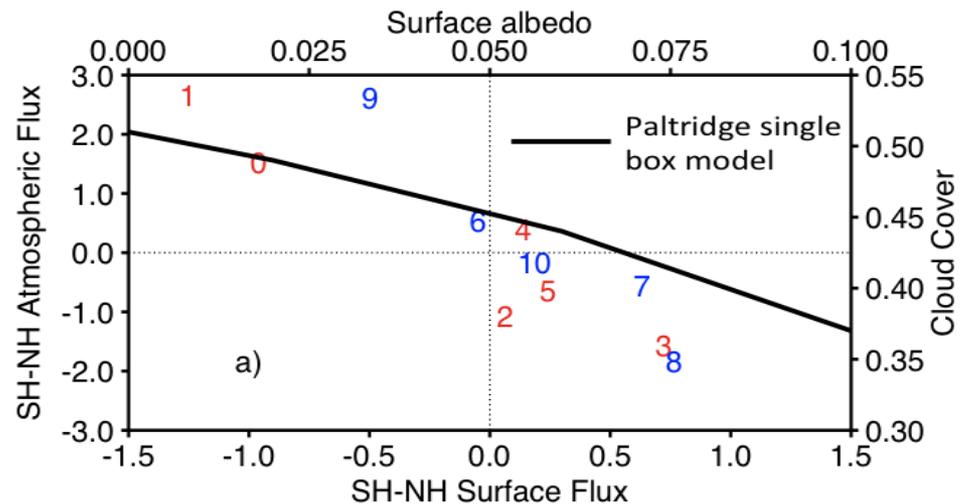
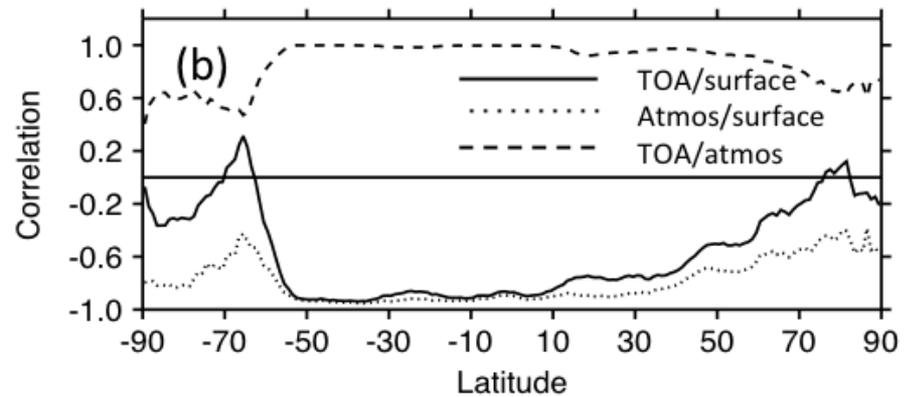
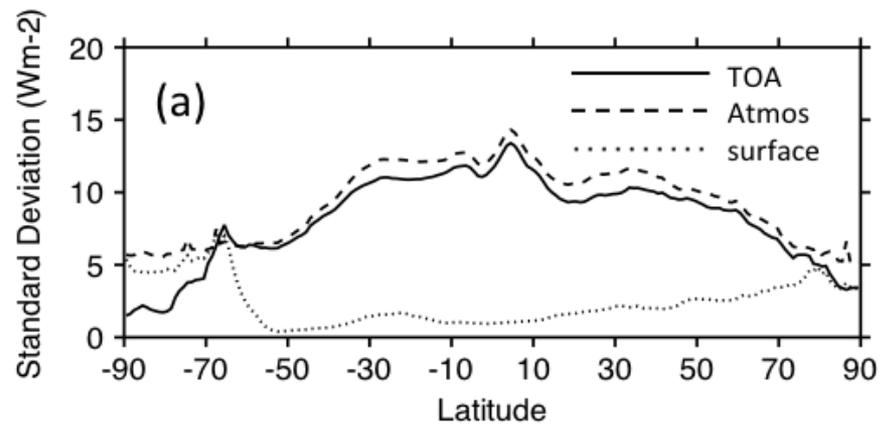
Interannual variability of the global-mean reflected flux $\sim 0.2 \text{ Wm}^{-2}$
 Local (1X1 degree) mean std deviation (deasonalized $\sim 9 \text{ Wm}^{-2}$)

CMIP5 Model Interannual variability

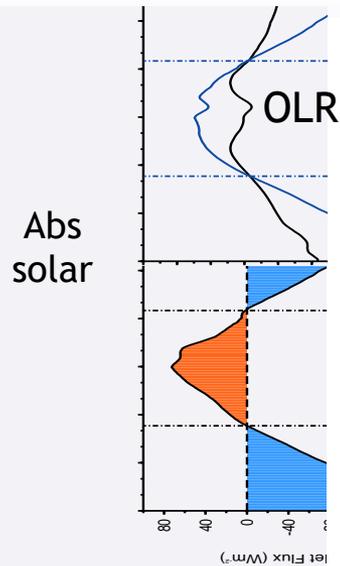


In the mean, model interannual variability is 4 times that observed

CERES Variability Between 2000-2010



Summary - The (near) symmetric energy balance

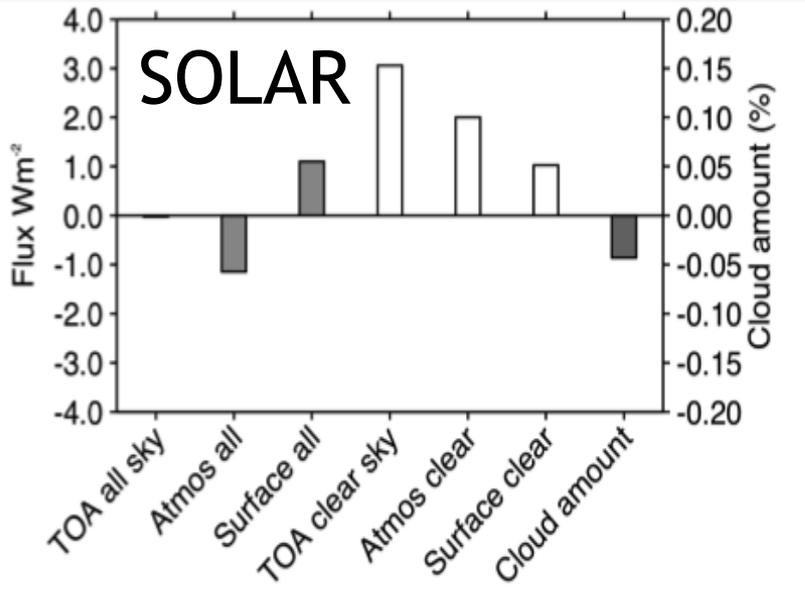


Scale (<i>x</i>)	Reflected SW (Wm ⁻²)		Outgoing LW (Wm ⁻²)		Net flux (Wm ⁻²)		Heat Accumulated (PW)		Sea Level Pressure (hPa)	
	Flux	$\sigma(x)$	Flux	$\sigma(x)$	Flux	$\sigma(x)$	<i>X</i>	$\sigma(x)$	<i>P</i>	$\sigma(x)$
Global	99.71	0.24	239.73	0.25	0.79	0.28				
NH	99.70	0.24	240.41	0.19	-0.16	0.25	-0.04	0.06	1011.8 (1010.3)	0.25
SH	99.73	0.39	239.05	0.41	1.75	0.39	0.44	0.10	1011.0 (1010.8)	0.27
Tropical NH	97.86	0.50	256.73	0.44	39.07	0.38	5.72	0.06		
Tropical SH	92.00	0.48	259.86	0.55	39.82	0.52	6.11	0.08		
Polar NH	102.11	0.54	218.45	0.49	-52.94	0.23	-5.76	0.03		
Polar SH	111.42	0.44	207.58	0.42	-55.80	0.44	-5.67	0.05		

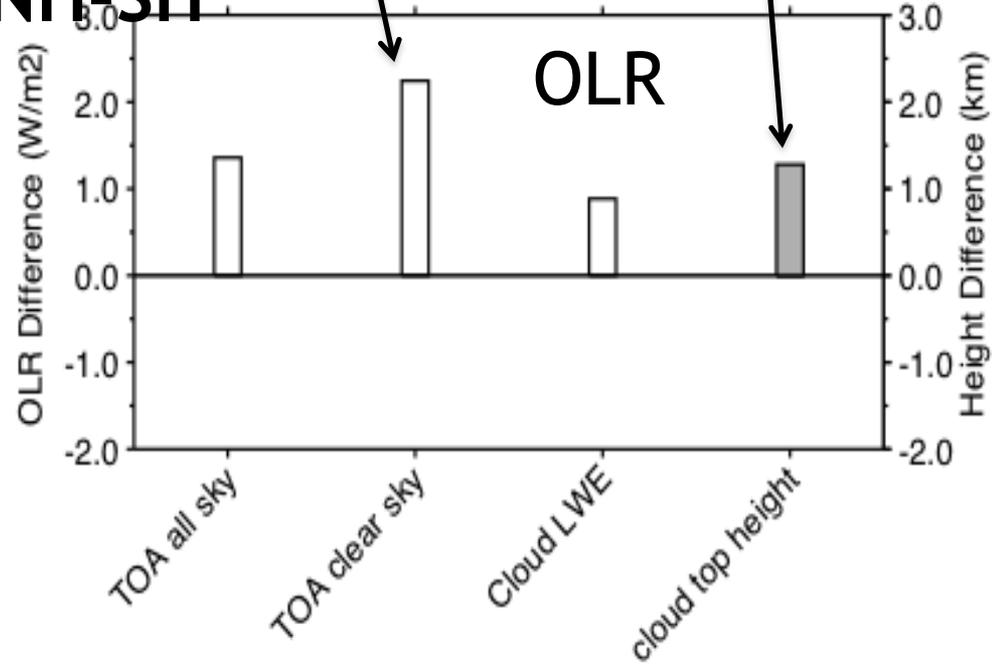
These are 11 year averages of the EBAF data

- 1) The NH is balanced , the SH gains heat - ie the ocean uptake occurs in southern oceans
- 2) This slight imbalance occurs through a slight OLR hemispheric asymmetry
- 3) Less obvious is the also near symmetry in meridional heat transport

Much of the clear-sky differences
(warmer NH) offset by higher (colder)
NH cloud tops



NH-SH

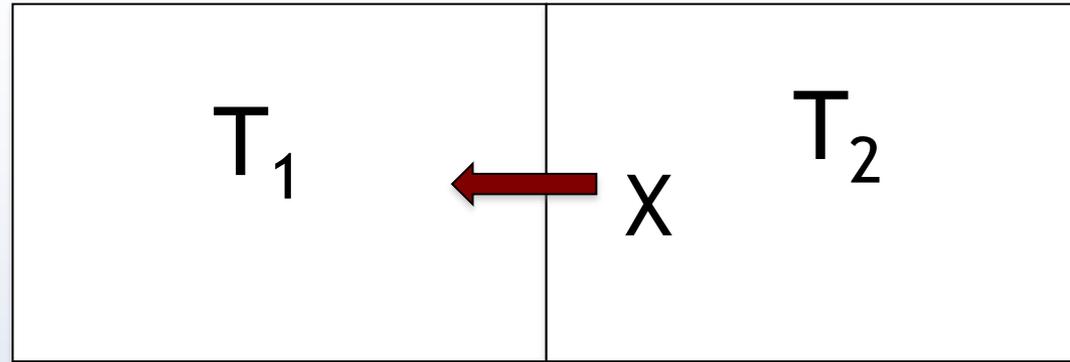


The regulation of the energy balance that creates this symmetry is achieved by cloud adjustments (both regulating solar fluxes and longwave fluxes)

Suppose
a steady
state
exists

$$N_1 = S_1 - L_1$$

$$N_2 = S_2 - L_2$$



SP

Eq

NP

On some time scale, steady state requires

$$N_1 + N_2 = 0; \quad N_1 = X, \quad N_2 = -X$$

Suppose $T_1 \neq T_2$ then a thermodynamic force $-\nabla T$ is produced driving a circulation between hemispheres. Fluxes of momentum and angular momentum across the equator must be zero implying the net mass flux is zero across the equator. We find (empirically from obs) that $X \sim 0$. Thus if

$$X=0 \longrightarrow N_1=N_2=0 \longrightarrow L_1=L_2 \quad (T_1=T_2) \longrightarrow S_1=S_2$$

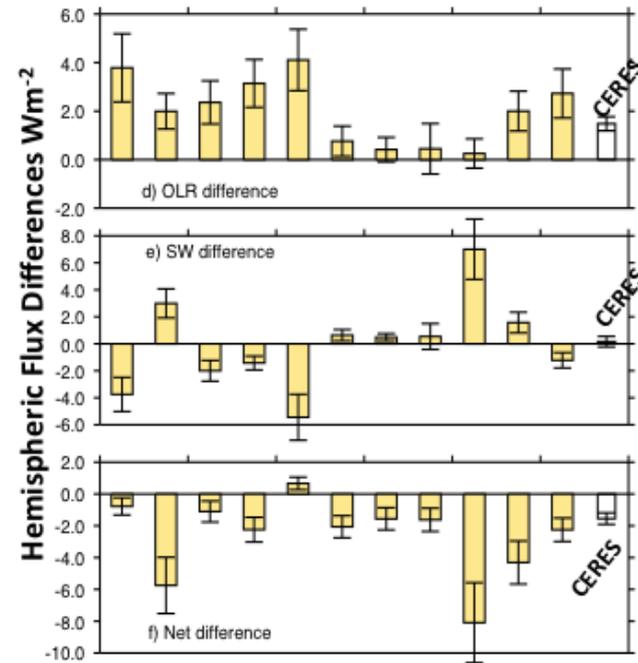
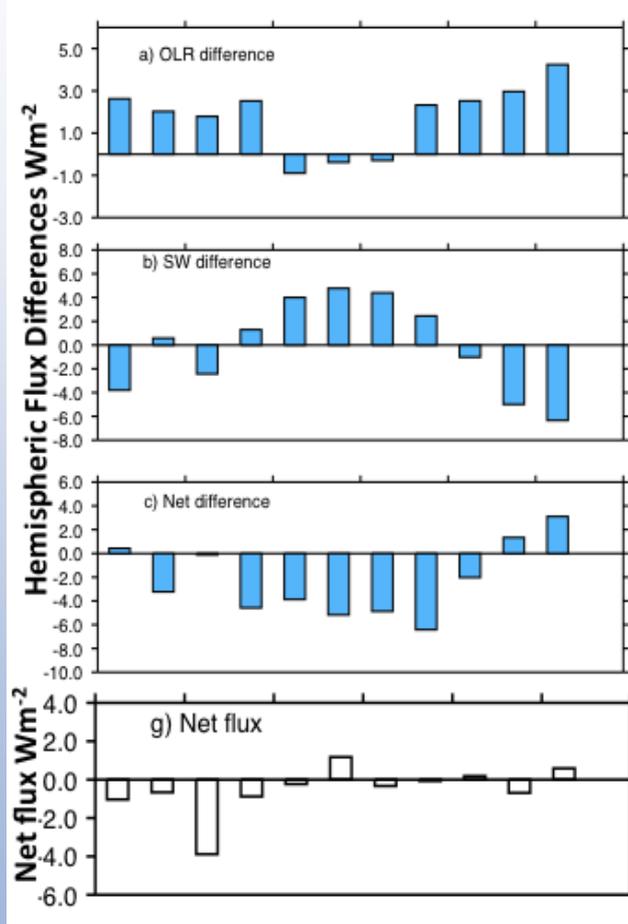
Summary:

- Is the Earth's Climate system constrained?
 - The reflected energy from Earth is highly regulated by clouds. The most dramatic example of this appears in hemispheric symmetry of reflected solar radiation
 - Hemispheric OLR also appears regulated and also by clouds
 - We hypothesize that the symmetry is not accidental but is a condition required for a steady state provides $X \sim 0$
- If some overriding constraint exist, what is its significance?
 - synchronized planetary response to asynchronized hemispheric (or more local) forcings?
 - Observed regulation suggests fundamental role of clouds are to produce negative feedbacks and not positive feedbacks as suggested in AR5?
- Are models similarly constrained?
 - Models don't have the same behavior as the observed Earth - they lack the same degree of regulation and symmetry. Does this really matter?

Important, unresolved questions remain - timescale?, data precision?, $X=0$?, further tests of steady state?????

Unresolved questions

CMIP5 500 year control CMIP5 historical -
Unchanged forcings, ... time varying forcings



We can't use present models to test ideas because they are neither balanced nor in

Key message points

- The sunlight reflected from Earth is highly regulated, exhibiting minimal interannual variability despite significant changes to surface albedo (sea ice)