What Spatiotemporal Sampling is Needed to Determine Earth Radiation Imbalance from GEO-MEO-LEO Constellation?

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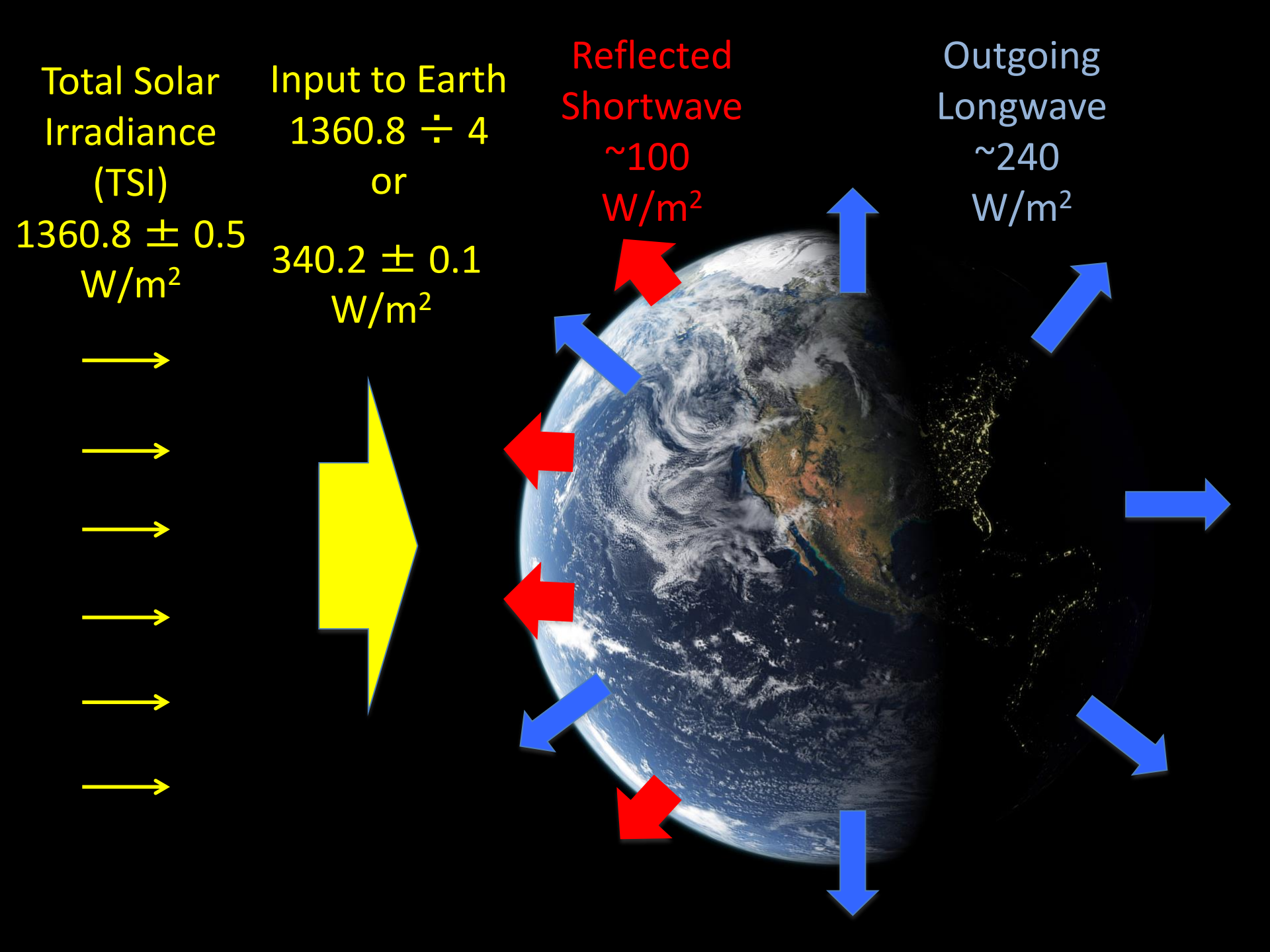
Outline

- **The Earth Radiation Imbalance (ERI)**

  Input Energy = Output Energy ?
- **Necessities for the flux measurement**
  - Absolute radiometric calibration
  - Spatiotemporal sampling
  - Angular sampling
- **OSSE study with MERRA data on spatiotemporal sampling**
- **Summary and future work**

The ERI Problem


Total Solar Irradiance (TSI)
1360.8 ± 0.5 W/m²
Input to Earth
1360.8 ÷ 4
or
340.2 ± 0.1 W/m²
Reflected Shortwave
~100 W/m²
Outgoing Longwave
~240 W/m²

Earth Radiation Imbalance (ERI) at the Top of Atmosphere (TOA)

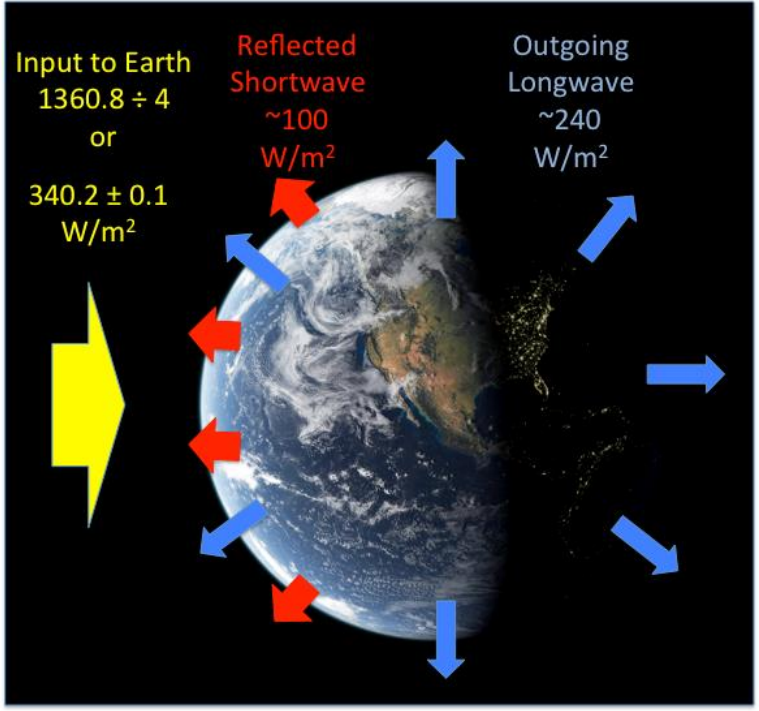
Difference between total input flux from Sun (TSI/4) and total outgoing radiation (TOR) flux

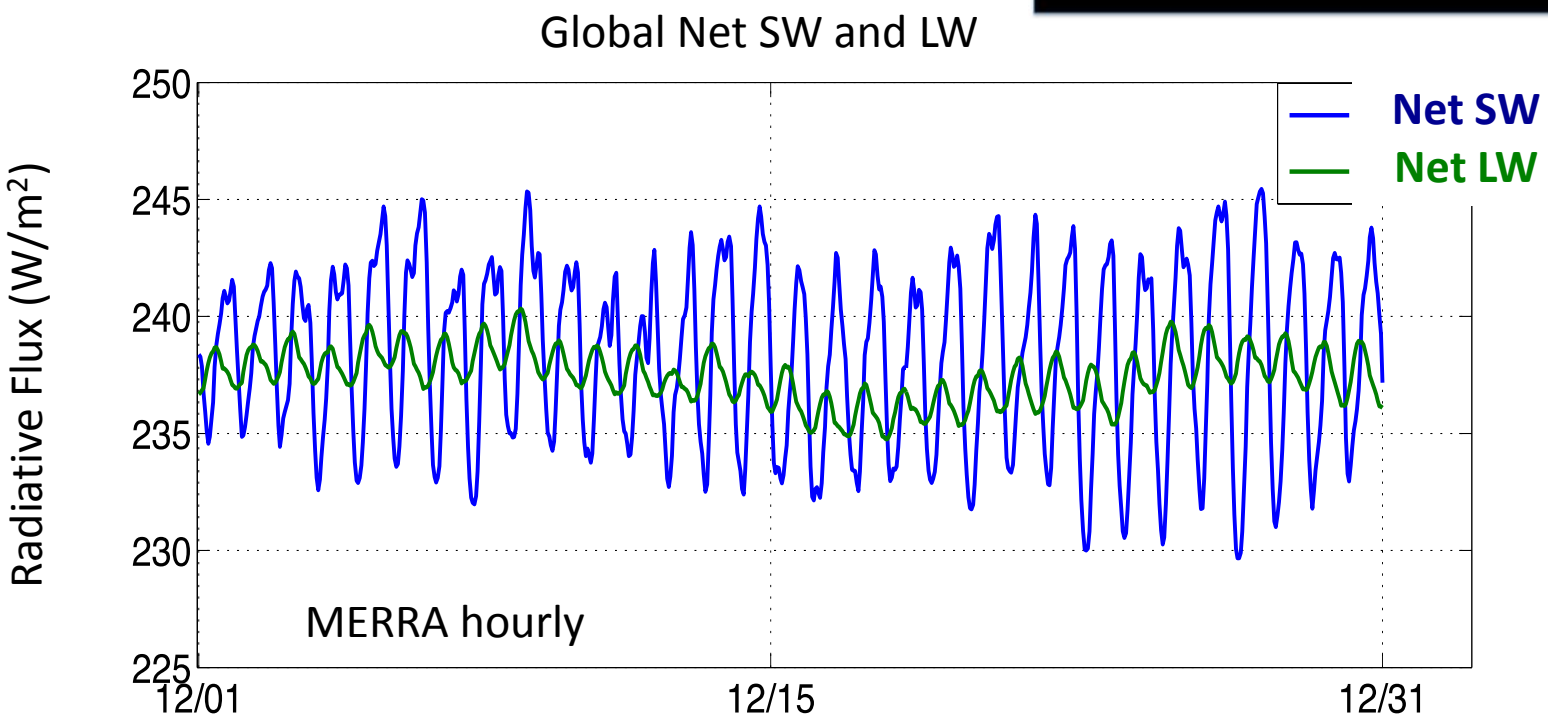
ERI = TSI/4 - TOR

TSI = Total Solar Irradiance (SW from SORCE/TSIS)

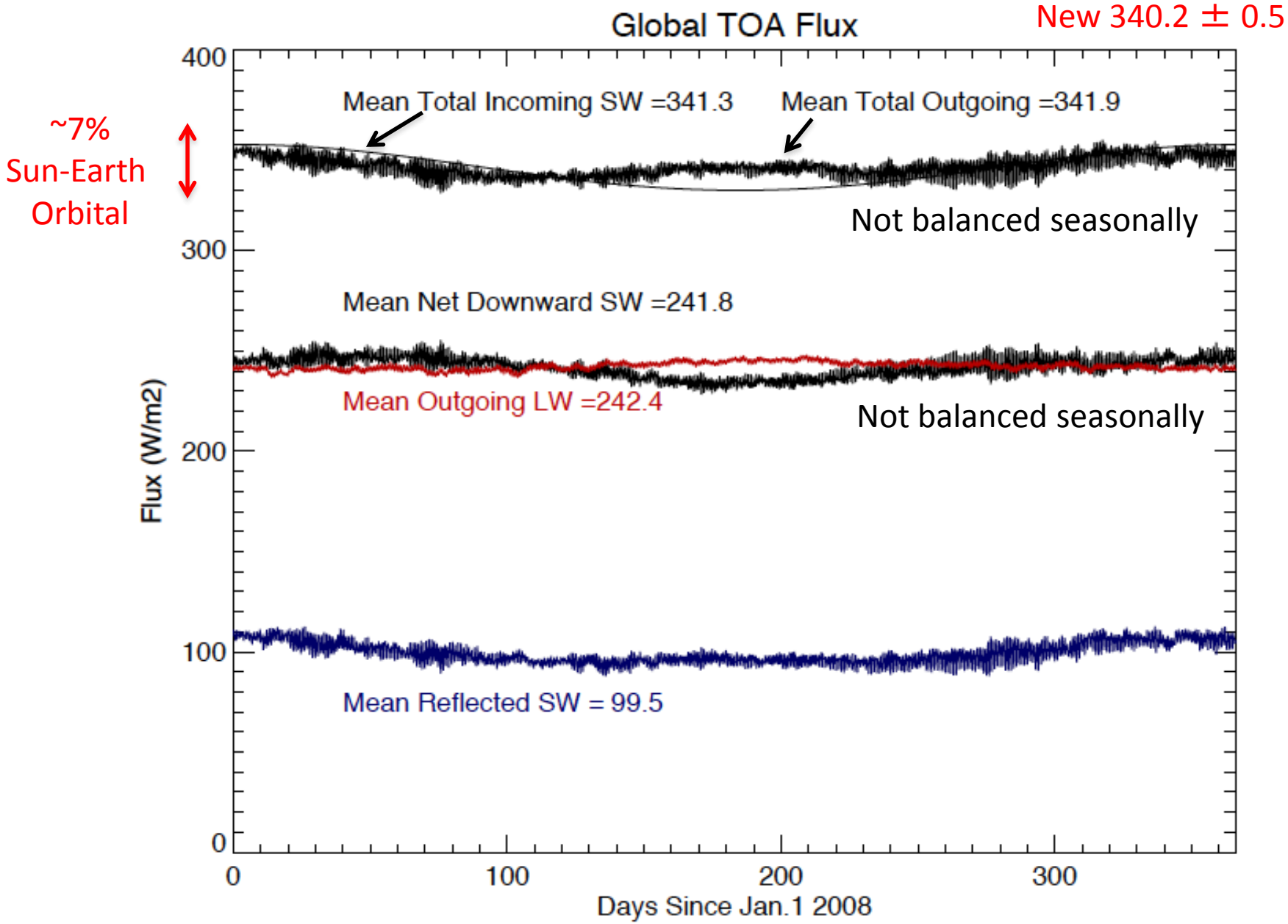
TOR = (reflected SW sunlight) + (emitted LW IR)

- Daily SW and LW not balanced
- Larger SW variability than LW
- SW and LW diurnal cycles lagged to each other





MERRA TOA SW and LW Radiative Fluxes



Earth Radiation Imbalance (ERI) Problem

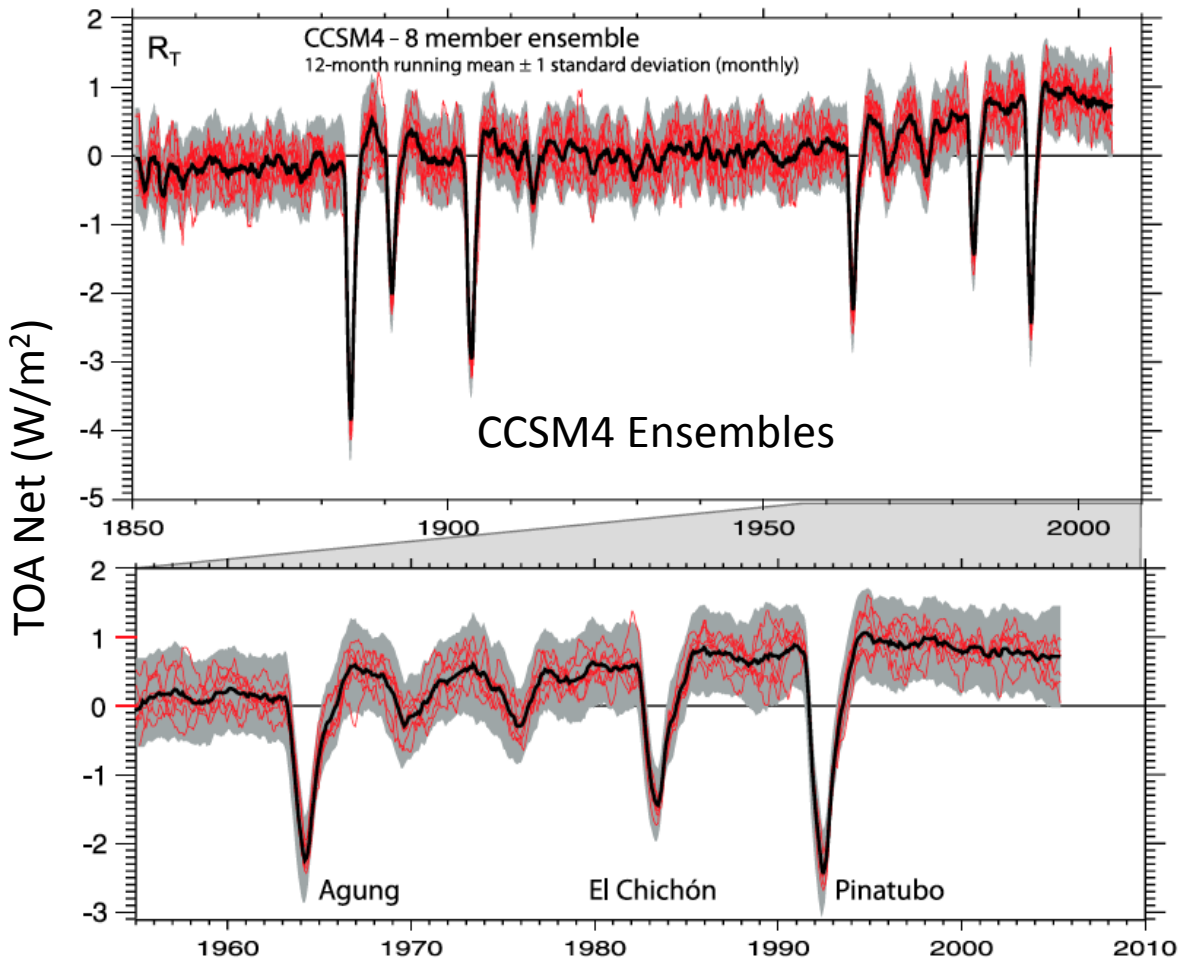
- Hansen et al. (2005)

  0.85 W/m²

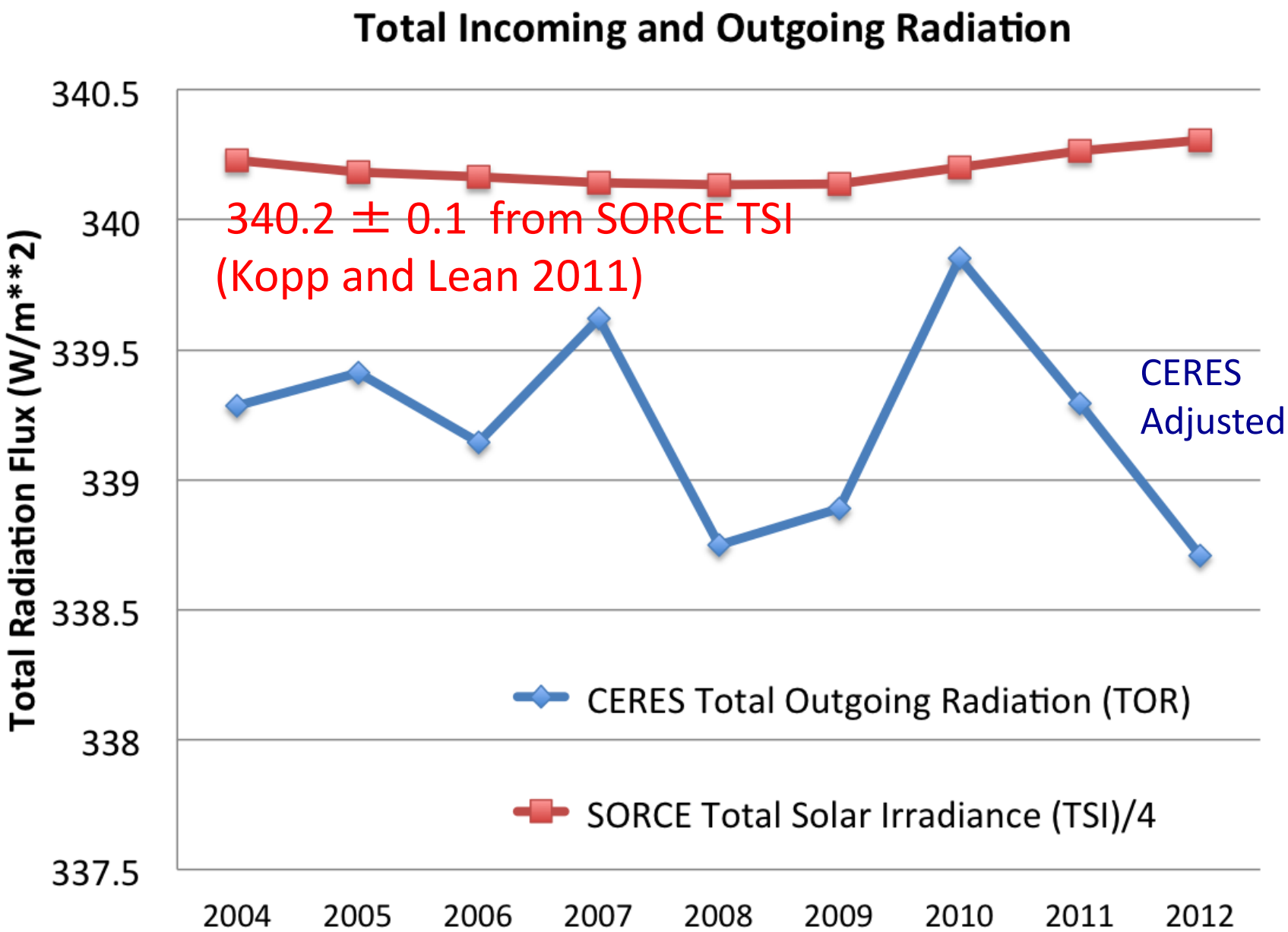
- Trenberth et al. (2009)

  0.9 W/m²

Trenberth et al. (2014)



Current Estimate from Space



Error budget ($W\ m^{-2}$) :

TOA net flux (1.25 lat/long)

[Wielicki et al., 1996]

CERES
(Loeb et al, 2008)

	Source of error	Monthly averaged global bias	Monthly averaged regional	Daily averaged regional
0.2-0.4 W/m^2	Angular sampling	0.9	1.2	3.5
?	Time sampling	1.1	2.3	8.1
4-5 W/m^2	Instrument calibration	1.6	1.6	1.6
5-6 W/m^2	Total	2	3	9
	Science requirement	0.2-1	2-5	5-10

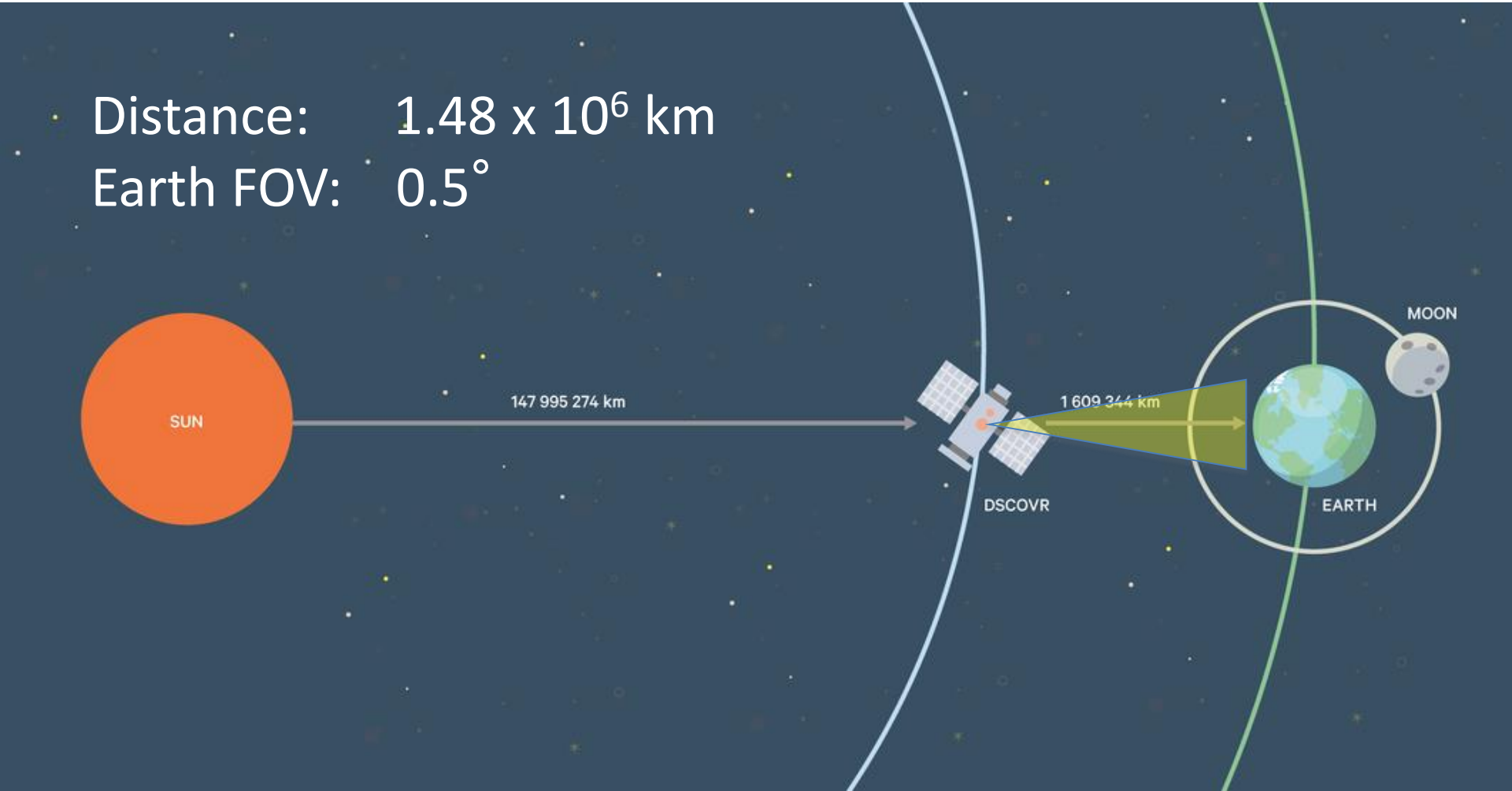
Challenges

1. Inter-calibration and accuracy of total power radiometers
   - 0.3 W/m^2 or 0.1%
   - Total power from broad bandwidth (0.1 nm – 200 μm)
2. Spatiotemporal sampling of Earth outgoing radiation for flux measurements
   - Large diurnal variations in reflected solar radiation due to clouds
   - Fluxes from anisotropic radiations (e.g., variable surfaces and clouds)

To be discussed further with OSSE from MERRA data

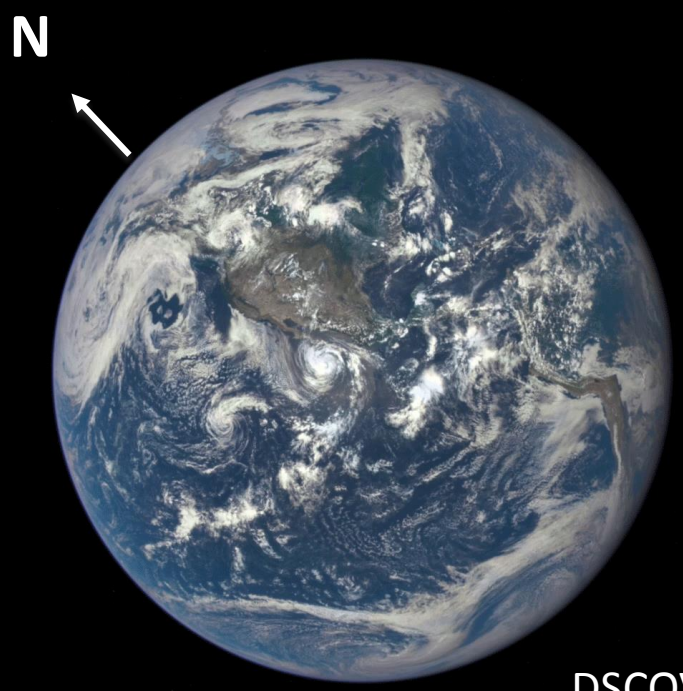
DSCOVR NIST Advanced Radiometer (NISTAR) from L1

(Launch in Feb 2015 – Present)



DSCOVR Earth Image from L1

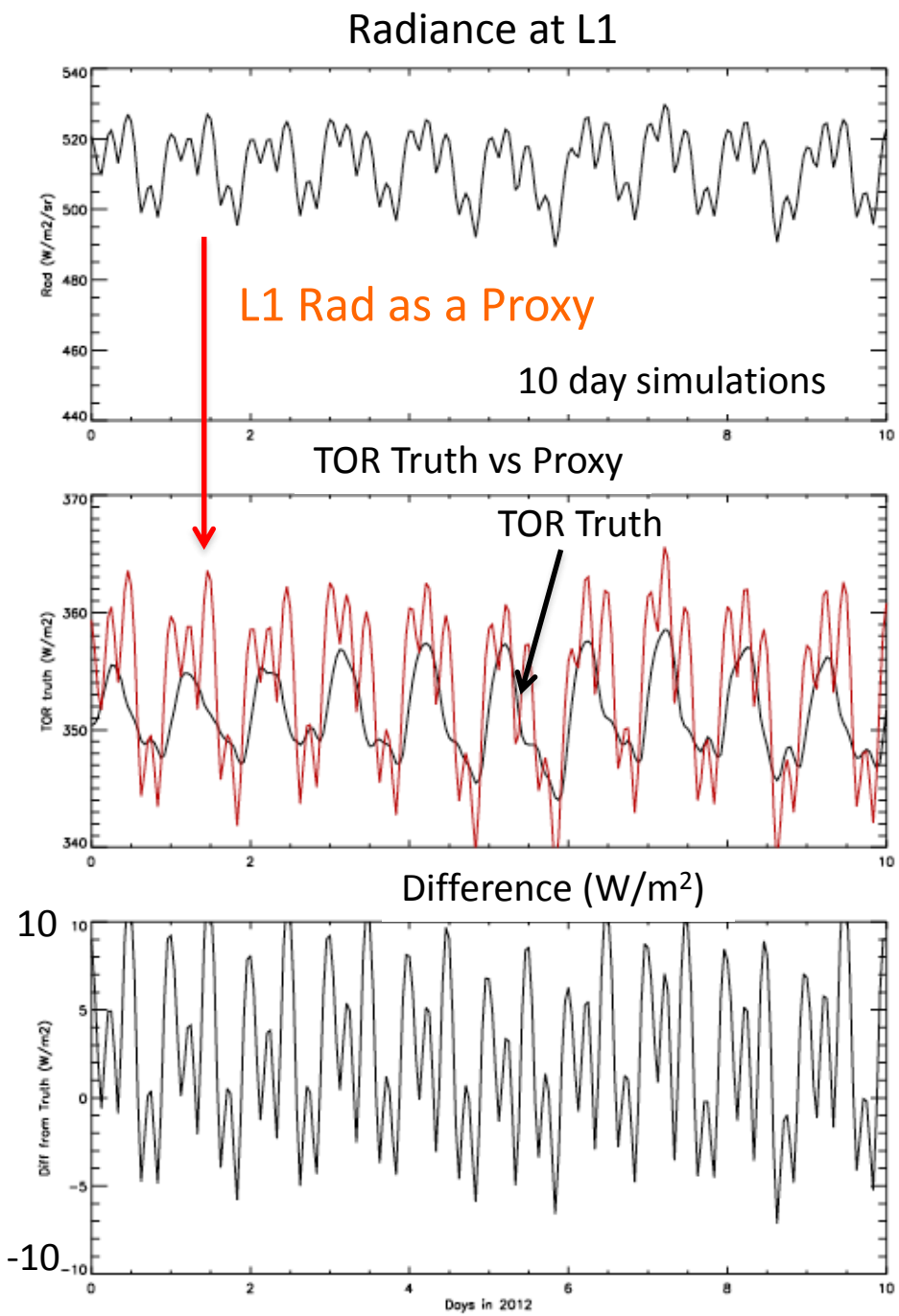
- Best view to capture the reflected solar variability, but not enough to determine the ERI
- PIs: Joe Rice (NIST), Steven Lorentz (L-1)
- Wide FOV: 1
- Accuracy: 0.1-1.5%
- Band-dependent:
  - Total (0.2-100 um)
  - Solar (0.2-4 um)
  - NIR (0.7-4 um)
  - VIS (0.3-1um)



DSCOVR/EPIC

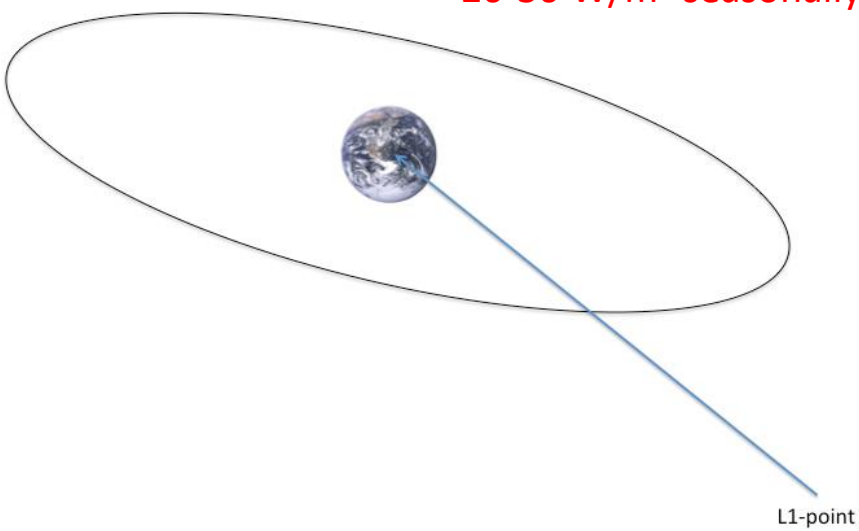
OSSE for L1 point

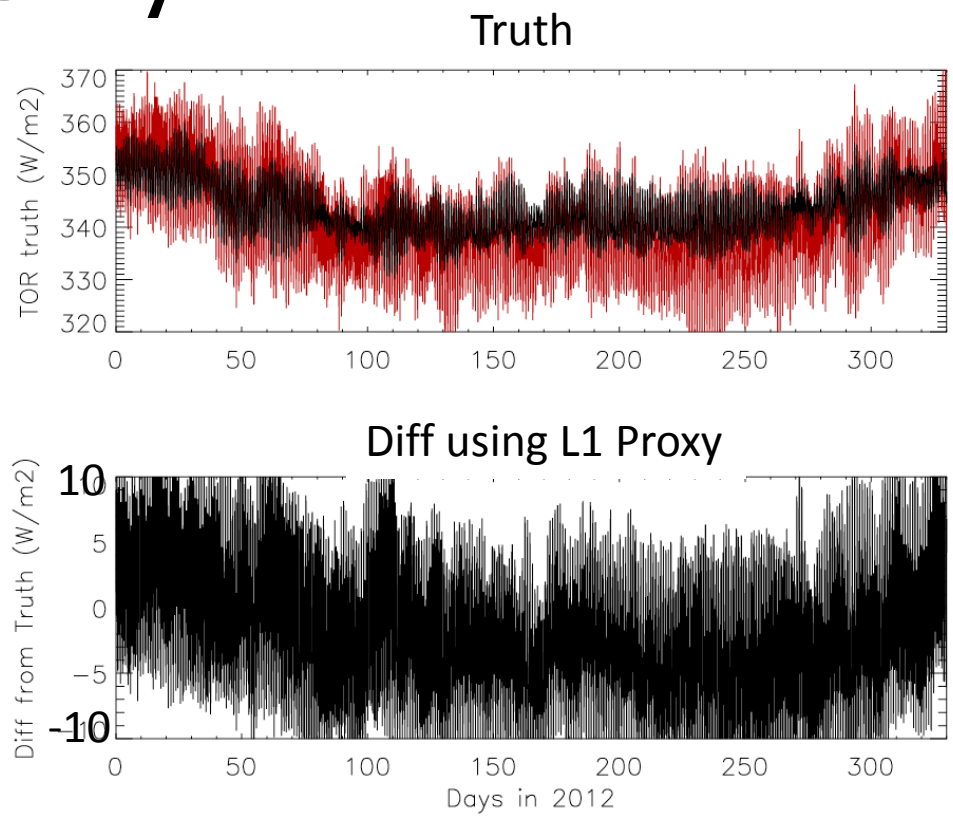
- **Best view to capture most of the reflected solar (SW) variability**, but not enough to determine the net flux (missing some LW) accurately
- Large variability in reflected SW due to clouds



L1 Only

10-20 W/m^2 hourly
20-30 W/m^2 seasonally





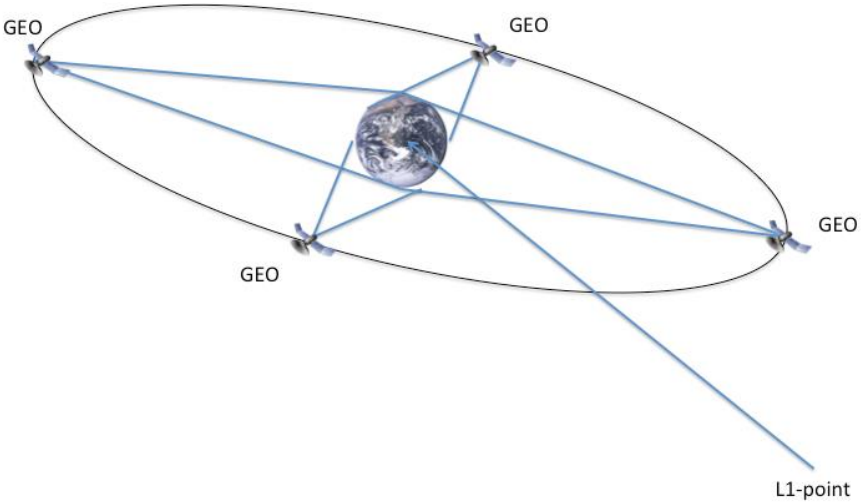
Weights:

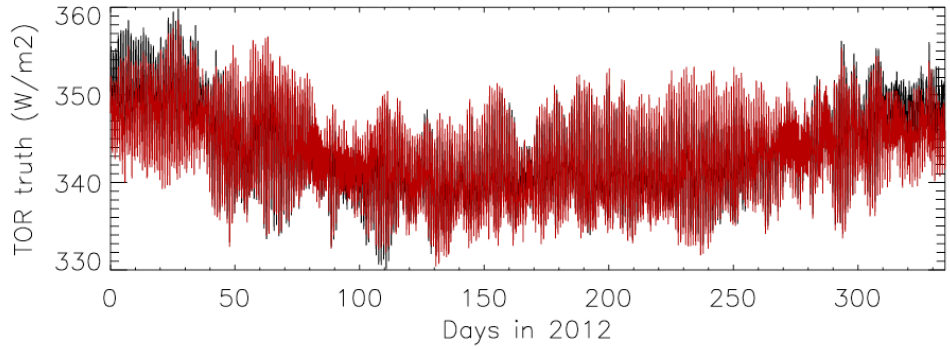
L1 0.69

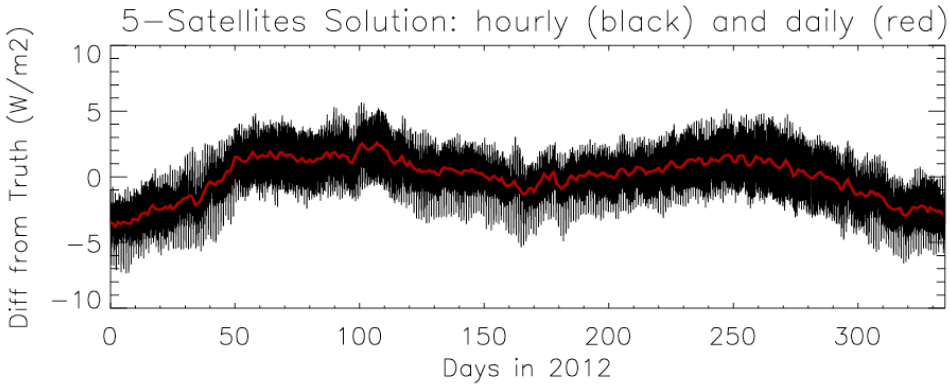
Std Dev:

Large in hourly and daily TOR

L1 + 4 GEOs







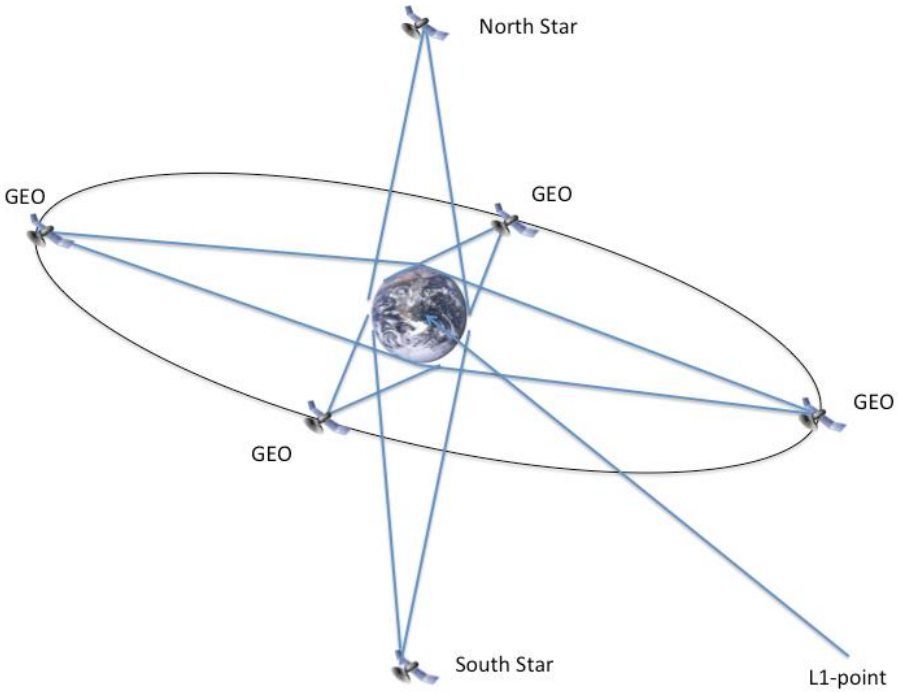
Weights:

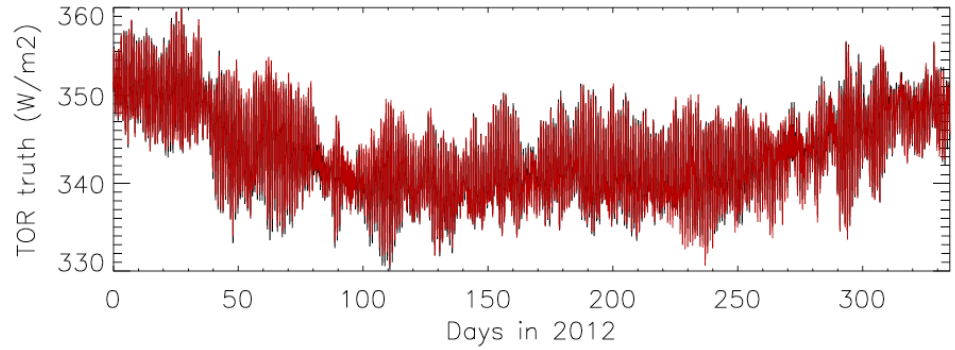
0.10536511	**0.11033598**	**0.11912748**	**0.11995442**	**0.19279463**
GEO_000	**GEO_180**	**GEO_090**	**GEO_270**	**L1**

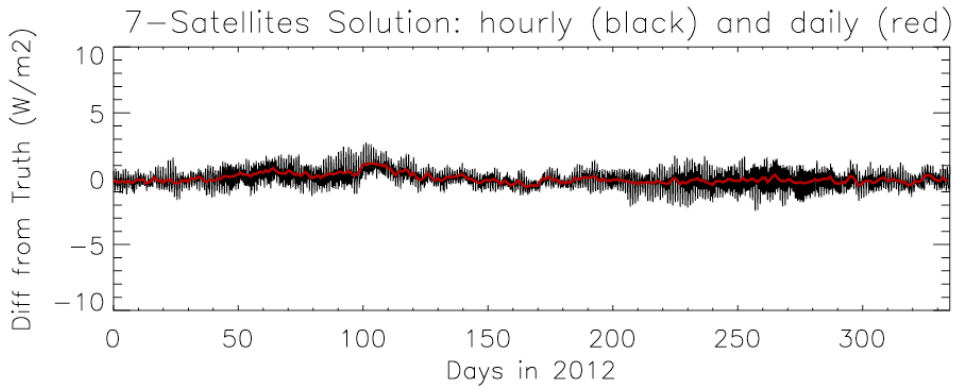
Hourly std = 2.2 W/m2

Daily std = 1.5 W/m2

L1 + 4 GEOs + 2 Poles





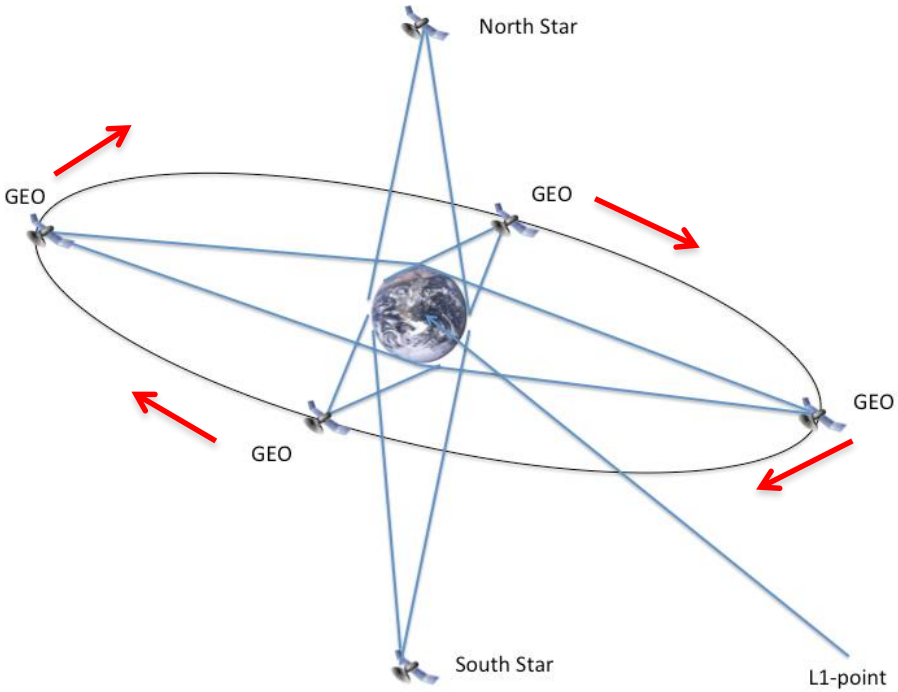


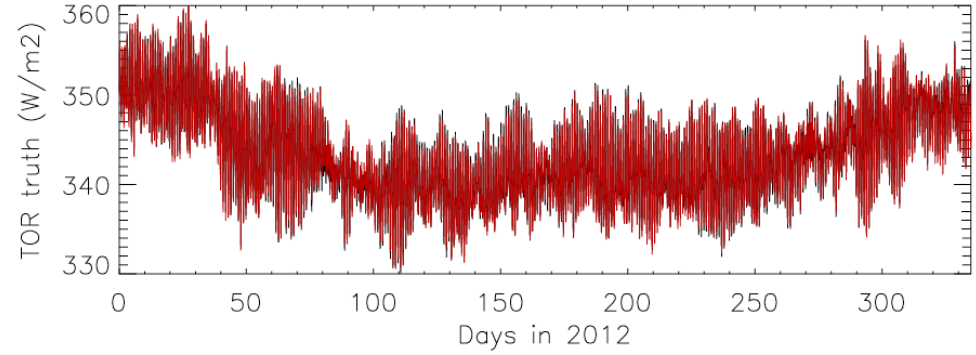
Weights:

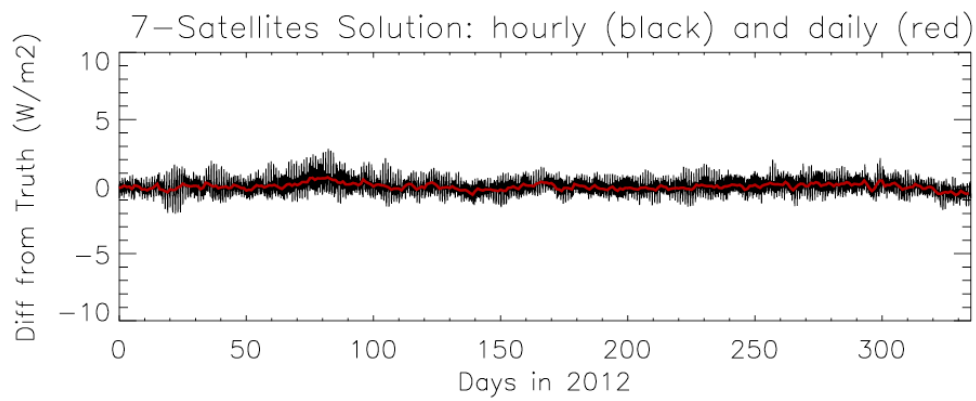
0.11	**0.122556**	**0.12264487**	**0.12303303**	**0.12419531**	**0.12843755**	**0.13184914**
L1	**GEO_045**	**GPS_N90**	**GPS_S90**	**GEO_225**	**GEO_315**	**GEO_135**

Hourly std = 0.67 W/m2
Daily std = 0.34 W/m2

L1 + 4 GEOs + 2 Poles (Optimal)







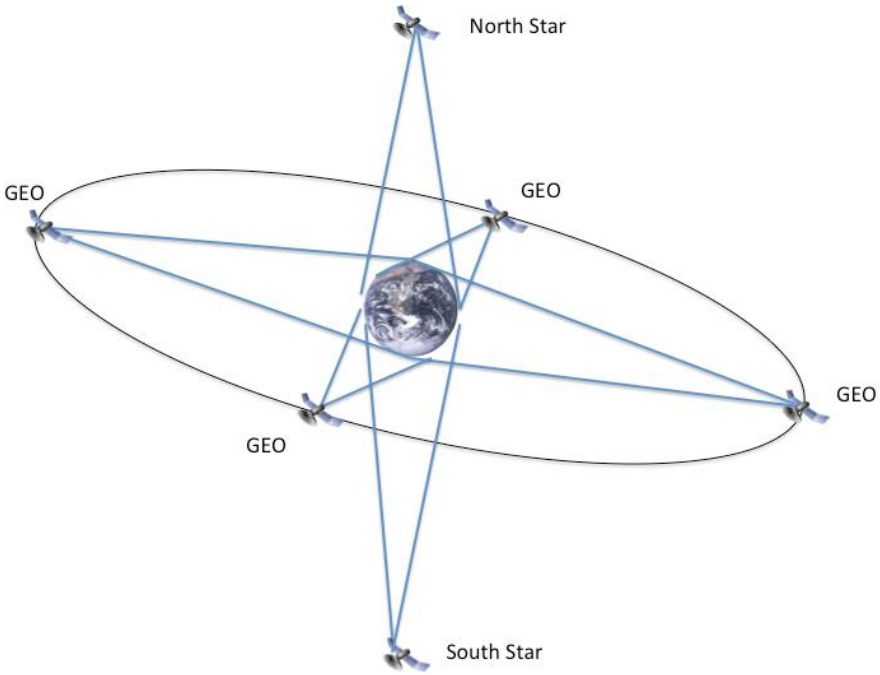
Weights:

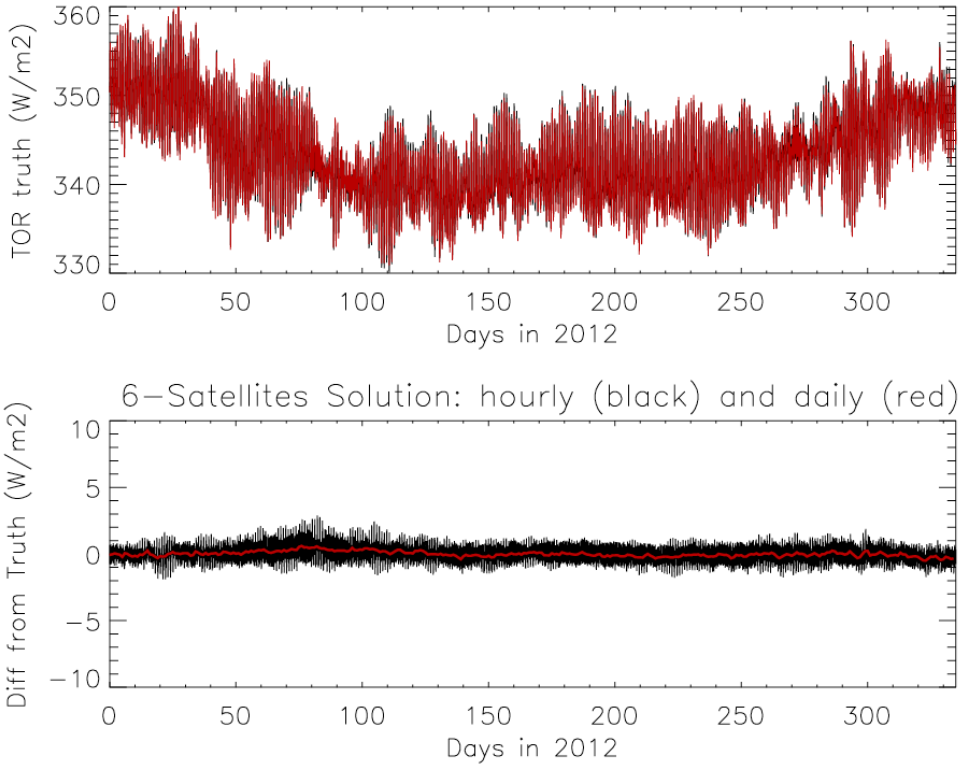
-0.06	**0.173793**	**0.17492548**	**0.19545343**	**0.19939669**	**0.19997128**	**0.20296063**
L1	**GEO_270**	**GEO_090**	**GEO_180**	**GEO_000**	**GPS_S90**	**GPS_N90**

Hourly std = 0.60 W/m2

Daily std = 0.23 W/m2

4 GEOs + 2 Poles

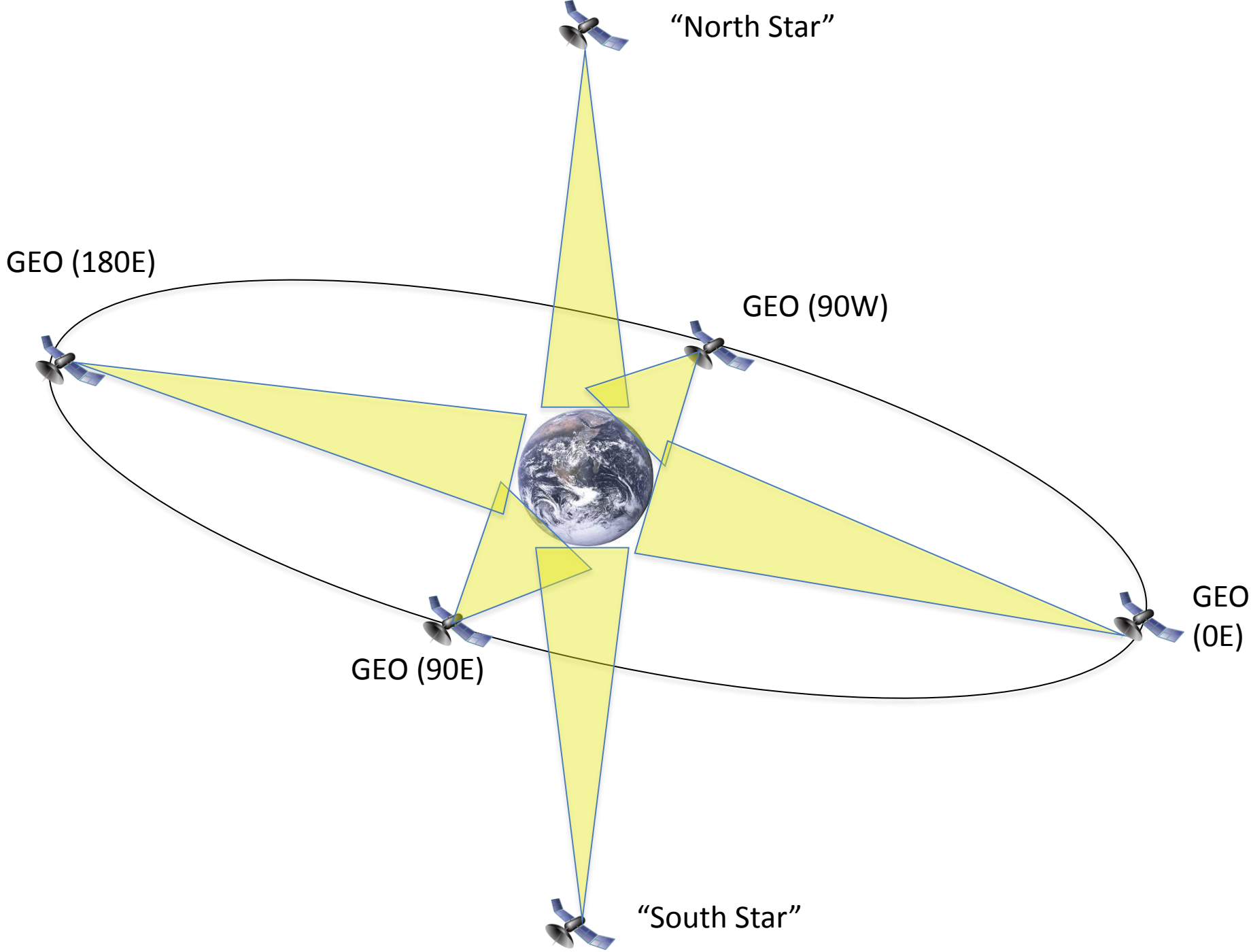




Weights for 6

0.15592214	**0.15692883**	**0.17256602**	**0.17484189**	**0.17808677**	**0.18090882**
GEO_270	**GEO_090**	**GEO_180**	**GEO_000**	**GPS_S90**	**GPS_N90**

Hourly std = 0.69 W/m2
Daily std = 0.19 W/m2


"North Star"
GEO (180E)
GEO (90W)
GEO (0E)
GEO (90E)
"South Star"

Summary

- Constellation with accurate (<0.3 W/m^2) wide-FOV radiometers can potentially provide accurate ERI measurements.
- GEO and MEO orbits are preferred over LEO for fewer satellites.
- Coherent spatiotemporal samplings are needed from the members of constellation.
- The polar satellites, “N-Star” and “S-Star”, are critical for reflected SW from snow/ice.
- Further OSSE studies, using MISR, are needed to evaluate effects of angular sampling.